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COLONIAL DEVELOPMENT

THE "Colonial Month", which was opened by H.M. The King on June 21, has been marked by three Parliamentary debates in each of which some aspect of Colonial welfare or development to which the contribution of the man of science is specially important has been stressed. In the third of these, on July 20, the Colonial Secretary, Mr. Creech-Jones, stated that some 211,000 persons had attended the Colonial Exhibition, and indicated that the exhibition would probably be continued for another month. The most significant feature of Mr. Creech-Jones's speech, however, was his reference to the dependence of Colonial development and welfare upon the availability of technical staff. Although during the past three or four years the Colonial Office has recruited 5,000 men and women for the administrative technical and professional posts of the Colonial Service, and Crown Agents have recruited a further 3,500, there are no fewer than 1,395 vacancies in the administrative and technical services. There are, however, signs that the position is improving in some technical grades. Efforts are being made to render the Service more attractive by improved conditions and provision of amenities and also to operate schemes of secondment from services in Great Britain.

It is against this background that the technical assistance now being made available from the United States for the backward areas under President Truman's Fourth Point must be appreciated, as well as the progress being made with the schemes under the Colonial Development and Welfare Acts*. A return of such schemes made under these Acts in the period April 1, 1948–March 31, 1949, has been made during the month. Development and welfare schemes total £10,627,509, of which £10,302,884 represents grants, while research schemes total £1,652,169, in which agriculture (£539,090) and fisheries (£558,009) claim much the largest share.

Merely to give the titles of a few of the largest schemes shows how important their long-term contribution to Colonial welfare and development should be. Thus, a scheme for soil conservation and agricultural development in Kenya will receive £611,000, £325,000 will be allocated for the development of rural water supplies in Uganda, £1,146,861 for medical and health services in Nigeria, £135,000 for geological survey in British Guiana, £1,100,000 for the Central Organisation for Colonial Geodetic and Topographical Surveys, and £325,000 for capital expenditure in the establishment of an East African Agriculture and Forestry Research Organisation and an East African Veterinary Research Organisation. Scarcely of less potential importance are many smaller grants, such as the £17,724 for establishment of a Coffee Research Station in Kenya, £43,400 for a rice research station at Rokupr (Sierra Leone), £20,000 for a West African Agricultural and Forestry

* Colonial Development and Welfare Acts. Return of Schemes made under the Colonial Development and Welfare Acts by the Secretary of State of the Colonies, with the concurrence of the Treasury, in the Period April 1, 1948–March 31, 1949. Pp. 56. (London: H.M. Stationery Office, 1949.) 1*s.* net.

Research Organisation, £18,000 for cytogenetical research on sugar cane in the West Indies, £55,255 for research into *Brucella melitensis*, £14,600 for an East African Bureau of Research in Medicine and Hygiene, £46,680 for an East African Medical Survey, and £31,874 for the Virus Research Institute at Entebbe. Among the larger research grants are £148,000 for fisheries research in West Africa, £135,000 for the construction of a fisheries research station at Hong Kong, £252,000 for the establishment of an institute for research and training in fish farming on Penang Island, Malaya, and £116,900 for the establishment of the Colonial Microbiological Research Institute in Trinidad.

These random examples of schemes illustrate both the range of the contribution of the man of science in this field and the extent of the demand for his services. They emphasize, too, the seriousness of a further point made by Mr. Creech-Jones on July 20—his warning that allocations under the 1945 Act might be completed in a comparatively short time and that further funds would then be required for urgent projects. In the debate on the second reading of the Colonial Development and Welfare Bill in the House of Lords on July 19, the Minister of State for Colonial Affairs, the Earl of Listowel, referred to the increasing rate of expenditure on research schemes and to the importance that such work should not be impeded by such a low annual ceiling as £1 million. Expenditure on development schemes was not increasing so rapidly; but unless the annual total was raised to £2 million, it would not be possible to expend the whole of the £120 million provided by Parliament before the Act expires in March 1956.

These proposals received a warm welcome in the House, particularly that for raising the ceiling for research grants, Lord Tweedsmuir expressing doubts as to the wisdom of an annual ceiling at all for this purpose, in view of the immense return which would be made by research leading to mastery of the rinderpest in Africa, the swollen-shoot disease in West Africa or the banana disease of the West Indies. Lord Strabolgi also referred to the rich dividends which would reward scientific research in such virgin territories, but the most interesting contribution to the debate came from Lord Hankey. Speaking specifically on Colonial research as a member of the Colonial Research Council and chairman of the Colonial Products Research Council, and foreshadowing the forthcoming report on Colonial research, he referred to the development of a promising substitute for linseed oil and the remarkable results of sugar research. The former, known as conophor oil, comes from a weed in West Africa, while promise is also shown by a rubber seed oil. Sugar research has yielded a substitute for blood plasma as well as an anti-freeze mixture and offers some prospect of a reduction in the price of sugar.

Lord Hankey paid a tribute to the help given, and initiative shown, by the Colonial Office in this field, and in acknowledging this tribute Lord Listowel took the opportunity of stressing the way in which the development of economic resources and of the social services and welfare was linked. A proper ratio has to be maintained between the development of communications, agriculture and industry and direct expenditure on social services, and it is the purpose of the ten-year plans to permit such co-ordination. Lord Listowel also referred to the part of private enterprise and said that this contribution has to be co-ordinated with that of Government and of the public corporations within the different territories.

To one of those Corporations Mr. Creech-Jones referred in his speech of July 21. The first report* of the Colonial Development Corporation, formed for the purpose of improving the standard of living of the Colonial peoples by increasing their productivity and wealth, points out that it is only by increased production and trade that these territories can earn the funds with which to purchase many of the commodities and supplies which they at present lack. The Board regards Africa as the most promising field for large-scale development, but has no lack of proposals of varying degrees of soundness. It is making every effort to work in close and friendly co-operation with private enterprise in the various territories, and the report shows very plainly that a great deal more caution is being observed in the selection of projects than has characterized the groundnuts scheme.

The report states frankly that the Board believes it necessary to avoid all-embracing and grandiose economic-development plans in favour of the selection of more concrete proposals, even if these are less ambitious in size and scope. It regards its task in judging projects as being to answer the question "Is this a fair risk in the circumstances?" Nevertheless, it believes it to be the intention of the Secretary of State that where doubts cannot be resolved it should prefer venture to caution, launch the project and do its best to overcome every obstacle to success.

Such a policy will minimize waste of public money, though it may result in some lost opportunities. This, however, may not be serious if there is effective co-operation with other bodies. For example, one of the long-term undertakings of the Corporation is a scheme for tung-oil cultivation in the Vipya Highlands. The Colonial Products Research Council and other bodies are obviously highly interested in such projects and may be able to help considerably in the early stages. It is thus unfortunate that one passage in the report suggests that the Board is a trifle impatient or resentful of the necessity of such co-operation, particularly as Mr. Creech-Jones in referring to the report on July 20 stressed the desire of the Government that the Corporation should enjoy the maximum freedom.

The very diversity of research and development in the Colonial Empire makes co-operation imperative, and it is also important, as the Board of the Colonial Development Corporation in concluding its report recognizes, that there must be wide public understanding, at home and among the Colonial peoples, of what is being done and the reasons behind the operations. No more welcome document† has appeared,

* Colonial Development Corporation. Report and Accounts for 1948. Pp. 188. (London: H.M. Stationery Office, 1949.) 1s. net.

† The Colonial Territories (1948–1949). (Cmd. 7715.) Pp. 136. (London: H.M. Stationery Office, 1949.) 2s. 6d. net.

from this point of view, than that presented to Parliament under the title "The Colonial Territories (1948–1949)". In addition to a general survey and chapters on the Colonial Office and the Colonial Service, political and constitutional progress, economic development, Colonial finance, the social services and international relations, it includes a diary of events of Colonial interest and a list of Parliamentary and Non-Parliamentary Papers published in the period. The Colonial Office is to be congratulated on the production of an invaluable reference paper which should make an important contribution to public understanding of Colonial affairs.

Besides the chapters already mentioned, there is one on research and surveys which, like Lord Hankey, anticipates slightly the forthcoming report on Colonial research. Another passage in this survey, however, received some attention in the debate in the House of Commons on July 1. Throughout the year, recognition of the importance of the preventive approach to medical problems has gained ground, and, as a result of the increasing determination of Governments to raise the social and economic status of the people, the effective control of certain major diseases is now regarded as an attainable objective. In the debate, which was raised on the adjournment, the prevention of tuberculosis in Africa was specifically mentioned, and Dr. B. Stross urged that the solution lay in training African medical men in Africa itself, and that funds should be granted from the Colonial Development and Welfare Fund. In replying, Mr. D. R. Rees-Williams welcomed Dr. B. Stross's suggestions and spoke both of the necessity of relying upon the Colonial Medical Service itself and the willingness of the Government to initiate an anti-tuberculosis campaign. Furthermore, this debate emphasized both that the development of technical education is one vital factor in Colonial development and that the co-operation of the Colonial peoples in their own development is as important as any contribution which the Mother Country can make to their future well-being.

These three debates once again demonstrated the existence in Parliament of a considerable body of informed opinion on Colonial affairs, and this survey, "The Colonial Territories (1948–1949)", itself shows how such opinion is being extended generally, not least among men of science themselves. Reference is made, for example, to the way in which the panel of consultants is leading to the closer understanding of Colonial health problems and to the formation of a body of expert opinion in Great Britain. Location of research on Colonial problems in different universities in Great Britain could contribute to the same, and it behoves the scientific workers concerned to lose neither those opportunities, nor the further opportunities provided by "Colonial Month" or the exhibitions or papers already mentioned, to help their fellow-citizens to appreciate what is involved and the way in which not only is economic development linked with social and political progress in the Colonies, but also the recovery of Great Britain and the whole Western World with the development and prosperity of the overseas territories.

AUTHORITY AND THE INDIVIDUAL

Authority and the Individual

By Bertrand Russell. (The Reith Lectures for 1948–9.) Pp. 125. (London: George Allen and Unwin, Ltd., 1949.) 6*s*. net.

LORD RUSSELL'S Reith Lectures were excellent to listen to and are just as good to read; the manner calls for nothing but praise. The matter, though not so completely immune from criticism, is valuable. It is essentially a political sermon based on the doctrine of J. S. Mill; a doctrine that is needed at the present day even more than it was a century ago. I use the term 'doctrine', but without the implication that Mill or Lord Russell is doctrinaire. They are empiricists in the best sense of the term. For them questions of authority and liberty, of what things should be decided by government and enforced by it, and what should be left to the initiative and judgment of the individual are to be answered from observation of what, in fact, makes for social welfare and what for the opposite. Social welfare means the welfare of individual persons and not of any abstraction, like 'State', 'race' or 'toiling masses'. Variety in human affairs is taken as being on the whole good, and uniformity as never better than a convenience. Thus the issue of *laisser faire* and private capitalism against collectivism becomes a secondary matter and one of expediency, not of principle.

In Mill's day the chief threat to welfare came from too much exercise of individual liberty and too little or ineffective government control. Now it is much more nearly the other way about. This change has very little to do with 'ideologies' but a great deal to do with technique, industrial and administrative, which works in the same direction all the time, whatever the political complexion of the government. Nearly two centuries ago Rousseau saw that a large society calls for more and more rigid authority than a small one. He could not foresee how far new technique would exaggerate that difference and also mechanize human relations. Nor could he foresee the great new principle of collective irresponsibility which governs so much of our lives.

Lord Russell's last lecture, on "Individual and Social Ethics", clinches his argument. He points out that we have to combine two kinds of morality. Civic morality depends upon respect for law—law, not the commands of persons in authority. Personal morality is something more elusive and not easily described, as it does not really depend on rules at all, but is a matter of initiative and may require the flouting of persons in authority. "Without civic morality communities perish; without personal morality their survival has no value." This is well said and cannot be said too often. The passages which follow, distinguishing means and ends, drive home the lesson that the State is only a means, and that apart from persons there are no ends at all.

Now as to criticism. Near the beginning too much attention is paid to Sir Arthur Keith's highly speculative views about human origins and, following on that, there is too much about the aggressive instinct in man. All human instincts that anybody has named are a bit bogus, like the old faculties of the mind. Aggressive habits, of course, are there in plenty; but that is a different story. These are

minor points. It is a pity that, in discussing the aims of government under the heads of security, justice and conservation, Lord Russell does not explain the meaning of justice as clearly as he does the other two. He had not room for everything; but room should have been found for this, as there is much confusion about it and also about the related notion of equality. Lastly, when explaining that personal morality may call for revolt against authority, he praises Socrates and Peter and Paul because they preferred to obey God rather than man. But he hastens to add that their theological beliefs are not really relevant. That may be, as a matter of strict logic. Yet, if the time comes when Lord Russell is called upon to drink the hemlock, the sole encouragement he will be able to give his friends will be to say, "This is the consequence of defying authority in obedience to private whim". A. D. RITCHIE

LIBRARY SCIENCE

Preface to Library Science

By Dr. S. R. Ranganathan. Pp. 203. (Delhi: University of Delhi; London: G. Blunt and Sons, Ltd., 1948.) 18*s*.

THIS book is in the nature of a mixed grill for two. Based on the inaugural lectures delivered in the Department of Library Science in the University of Delhi in 1947, it consists, in part, of an attempt to establish that there is a library science and, in part, of a practical exposition to students of what Dr. S. R. Ranganathan understands by the expression "Library Science". The latter is essentially a dissertation on the five 'laws' or principles of library science which Dr. Ranganathan enunciated nearly twenty years ago: books are for use; every reader his book; every book his reader; save the time of the reader; the library is a growing organism. Elementary as these principles seem, Dr. Ranganathan shows how they cover the essential functions of any type of library, and how ruthlessly they challenge the formalism and pedantry that sometimes mar the usefulness of a library and the essential co-operation between user and library staff.

Of the other part of the book, flavoured though it is with a touch of philosophy and of autobiography, it must be said that the author scarcely establishes his thesis. Dr. Ranganathan appears to be arguing that there is a library science in the sense in which we can speak of a science of chemistry, or physics, or geology. The evidence is thin. Nowhere does he demonstrate the existence of a discipline approaching that which would justify the establishment of a university faculty or department. There is an apposite passage among the conclusions of the recent Nuffield College Statement on "The Problem Facing British Universities". "If we are to be frank with ourselves we have to recognize that the great majority of occupations involve so restricted a range of theoretical or scientific knowledge that they can be taught just as effectively and much more economically in the occupation than in a University."

Dr. Ranganathan's vision of an expansion of professionally trained library staff in India from less than two hundred to a million in thirty years has rendered him at least liable to overlook the difference between an academic discipline and professional training or qualification. That the librarian needs a professional training and qualification for many purposes is not in dispute; how they are best to be obtained is another matter, and the answer may well be found, on economic considerations, to lie in courses parallel with those offered in colleges of technology. Whether or not we can rightly speak of a library science, there is a technique of librarianship only to be acquired by training and study, and the real question is whether that training should be given before or after actually taking up work in a library.

While in this book misprints are not excessive, for the quality of production its price is high, and the bibliographic standards are poor. There are some surprising omissions from the bibliography, and even allowing for the fact that it details merely books prescribed for the diploma examination at the University of Delhi, the omission of all dates and publishers is a lapse from standards of scholarly exactitude which is unfortunate in a book designed, in part at least, to justify the use of the term "Library Science". R. BRIGHTMAN

JET PROPULSION AND GAS TURBINES

Principles of Jet Propulsion and Gas Turbines

By Prof. M. J. Zucrow. Pp. xiv+563. (New York: John Wiley and Sons, Inc.; London: Chapman and Hall, Ltd., 1948.) 39*s*. net.

THE main object of this book is the presentation of the basic theory of jet propulsion and the thermodynamics of the gas-turbine and rocket types of engine. The layout follows a logical sequence, on the whole, although it is somewhat spoilt by two chapters on aircraft and propeller performance being inserted between the two sections of the book dealing with, respectively, basic theory and its application to engine design and performance.

The first section of the book, covering four chapters, presents the basic theory starting from fundamental principles and leading to the thermodynamics of gas flow. The subject is well covered, and the treatment is sufficiently lucid for the serious reader to be able to appreciate thoroughly the application to engine design and performance. This first section of the book also contains useful and up-to-date data on the thermodynamic properties of air.

After dealing with the basic theory, one would have expected the author to pass on to the application to engine design and performance, instead of which the reader is confronted with the two chapters on aircraft and propeller performance. Most of the subject-matter of these two chapters can be found in text-books on applied aerodynamics, and for its proper appreciation, especially the section on jet-aircraft performance, it should have followed the final section of the book dealing with the purely engine side of the subject.

In this final section, the basic theory of the first four chapters is applied to engine design and performance. As an introduction, the reader is treated to the now well-known thermodynamic analysis of the power-producing gas turbine cycle, which seems rather misplaced in a book dealing with jet propulsion. In his treatment of the gas-turbine jet engine, the author can be taken to task over many things. The historical survey is not as up to date as it could have

been, and performance theory analysis is over-simplified; in particular, the omission of the non-dimensional approach to performance plotting is more than regrettable. So far as compressor design is concerned there are again important omissions, though the simplified aerodynamic treatment of the axial compressor will be found useful as an introduction to the subject. In dealing with turbine design, the author reverts to a treatment that has now been largely superseded, containing, as it does, the now out-moded distinction between impulse and reaction types. The chapter on rocket-power plants is both comprehensive and instructive, and the book concludes with a useful survey of the properties and constituents of alloys suitable for high-temperature service.

Summarizing, therefore, while the book may be said to provide a useful exposition of fundamental theory, it can scarcely be recommended as one giving an up-to-date treatment of the aerodynamics and thermodynamics of gas-turbine jet-engine design and performance.

S. J. MOYES

NEW DEVELOPMENTS IN PHYSICS

Reports on Progress in Physics

Vol. 11 (1946–47). Pp. iv+462+11 plates. (London: Physical Society, 1948.) 42*s*. net; to Fellows, 25*s*. net.

WHEN introduced in 1934, "Reports on Progress in Physics" was intended to be a series of annual reports. In 1942, owing to the need for economy in time and material, a change in policy was made, for what was thought would be only for the duration of the War, by publishing one volume every second year. Unfortunately this temporary measure had to be continued after the cessation of hostilities; but it is now hoped that the volume under review will be the last of the two-year volumes. Indeed, the welcome news has recently been given that Volume 12 is already in active preparation and should be published later this year.

In earlier volumes the responsibility for production was taken by a general editor; first by Prof. Allan Ferguson, and then, more recently, by Dr. W. E. Mann. For Volume 11, a small editorial board, under the chairmanship of Dr. G. B. B. M. Sutherland, was set up.

Several branches of physics and technology are covered by the thirteen separate articles in Volume 11. Five articles are grouped together under the general heading of meteors, comets and meteoric ionization; four of them are based on the lectures delivered at the Physical Society Conference held at Manchester in March 1947 (an account of this Conference was given in *Nature*, **160**, 76; 1947), and the fifth, by Dr. R. W. B. Pearse, dealing with spectroscopic observations on comets, meteors and meteorites, has been added for the sake of completeness. Both the astronomer and the physicist will find much of interest in this group of reports, for much new information on meteor activity has only recently been obtained by the use of refined radio techniques which were developed during the war period.

In the authoritative and masterly report contributed by Prof. E. C. Stoner on ferromagnetism, the background to the more recent developments in this subject, that is to say, the general ideas and principles gained from investigations up to about 1934, together with the theoretical and experimental work done on intrinsic magnetization since 1934, are described. Although the published work on ferromagnetism is very extensive, and several reviews dealing with particular aspects have appeared within the past fifteen years, Prof. Stoner's article is the first dealing specifically with ferromagnetism to appear in the "Reports". It is to be followed in the next volume by a further report by Prof. Stoner on recent work on magnetization curves and associated phenomena.

Nuclear physics is represented by three articles. Recent experimental work on the recoil of nuclei in beta-disintegrations, with particular reference to the neutrino, is reviewed by B. Pontecorvo. The results which have been obtained, the limitations of the method, possible future developments and the most promising techniques are clearly stated. The more recently discovered cases of radioactive branching are admirably classified by Prof. N. Feather, and the phenomenon is discussed in general terms. The illustrated and informative account of electrostatic generators for the acceleration of charged particles, contributed by Prof. J. R. van der Graaff and co-workers, should prove most useful, for many laboratories are now actively engaged in constructing large electrostatic accelerators for use in nuclear research.

It is largely due to the work of Prof. D. R. Hartree that the extra-nuclear structure of many atoms has been calculated. The Hartree 'self-consistent field' method, and the Fock 'self-consistent field with exchange' method, together with various other modifications, as well as a table summarizing the results of the various calculations on the different atoms, are all carefully and concisely explained by Hartree himself in his article entitled "The Calculation of Atomic Structures".

Two other important recent developments in physics, the detection of infra-red radiation and the application of infra-red methods, and the radio-frequency spectroscopy of gases, are dealt with in articles by G. B. B. M. Sutherland and E. Lee, and B. Bleany, respectively. Ultrasonics research and the application of ultrasonic methods to the study of the gaseous, liquid and solid states of matter are the subject of a report by C. Kittel; and, in the technological field, articles by W. F. Berg on the latent-image formation in photographic silver halide gelatine emulsions, by H. Friedenstein, S. L. Martin and G. L. Munday on the mechanism of the thermionic emission from oxide-coated cathodes, and by H. Moore on physics in glass technology, are of considerable interest. The study of natural evaporation is mainly part of meteorology, but it overlaps into many other scientific fields; and the survey of evaporation in Nature given by H. L. Penman should be of value not only to meteorologists, but also to those interested in the formation and distribution of soils and in the growth of crops.

All the reports are accompanied by extensive bibliographies, and the volume has an excellent author index. Volume 11 is well up to the high standard of its predecessors. The demand, it is understood, is already great, and doubtless it will soon, most regretfully, become, like most of the previous volumes, an 'out-of-print' edition, with a long waiting list of applicants for second-hand copies. The Physical Society is indeed to be congratulated on another excellent "Progress Reports".

S. WEINTROUB

Birds in Camera

Twenty-five Years of Bird Photography. By Walter E. Higham. Pp. 127 (83 plates). (London and Glasgow: Wm. Collins, Sons and Co., Ltd., 1949.) 15*s*. net.

THIS book by Walter Higham is a book of photographs, and even among present-day bird photographs of excellence they stand out, not only because of their technique, but also because of their composition. They are, perhaps, more than any photographs of birds which I have seen, real pictures and give delight when looked at again and again.

Some of the photographs show unusual nesting haunts. The author's picture of a curlew approaching the nest and eggs in a ploughed field portrays a site I have not previously known this shy bird to occupy, although I have often seen oystercatchers' nests in ploughed fields. One of his illustrations is of an almost white lapwing on the nest. A particularly beautiful photograph is of a sand martin in flight, its primaries outspread. The shadow of the bird is clearly seen outlined against the sand behind it. A woodcock with newly hatched young and four pictures of a ringed plover approaching or on its eggs, in open sand with no nest of any kind, are among other outstanding photographs in the book.

Mr. Higham gives two striking pictures of gannets on the Bass, one of a bird about to alight, the other of two birds sailing past in graceful, characteristic attitudes. There is a lovely photograph of a swallow on her nest of mud. It is easily the best swallow photograph I have seen. An interesting observation (p. 72) is that the author of the book saw a sheld-duck smoothing with her tail the footprints she had made while leaving her nesting burrow. My one criticism of this fine book, which the publishers have produced in a worthy manner, is its title. "Birds in Camera" is ambiguous and scarcely does justice to the contents. SETON GORDON

A Descriptive Guide to the Libraries of the University of Leeds

By Dr. Richard Offor. Pp. 134+6 plates. (Leeds: Brotherton Library, The University, 1947.) 6*s*. 6*d*.

IN completing, as his last task of University librarian and keeper of the Brotherton Collection, this guide to the University library and the various departmental or specialist collections, Dr. Richard Offor has rendered a real service not only to the University of Leeds but also to librarians and students elsewhere, and it is welcome news that it is proposed to keep the guide up to date by a series of annual supplements. Even when the "World List of Scientific Periodicals" and the "Union Catalogue of the Periodical Publications in the University Libraries of the British Isles" are again available, guides of this order will have a real value to the serious student, not merely because fuller information is supplied, but also because the arrangement facilitates some reasonable judgment as to where 'browsing' is likely to be most profitable.

The arrangement is entirely different from that of the "Reader's Guide to the British Library of Political and Economic Science": Dr. Offor's guide is more purely descriptive and is not intended to teach simultaneously the use of a library. After dealing geographically with the main collections, he gives details of general works of reference and bibliography, general periodicals, general language and literature, and general science and technology, before indicating the serial holdings and special collections under individual subjects in alphabetical order. There are a few anomalies; but they will not affect the warm welcome which must be given to an admirably produced and moderately priced volume.

R. B.

Atomic Energy

Being the Norman Wait Harris Lectures delivered at Northwestern University. By Dr. Karl K. Darrow. Pp. ix+80. (New York: John Wiley and Sons, Inc.; London: Chapman and Hall, Ltd., 1948.) 12*s*. net.

HUNDREDS of physicists have, like Dr. K. K. Darrow, been called upon to explain the basis of atomic energy to a non-scientific audience; but few can have brought to the task the art, experience and knowledge that are happily mingled in these four lectures.

The usual road must be followed: atoms must be described and their structure explained, and the electrical forces that hold them together must be contrasted with the much stronger forces that bind neutrons and protons into nuclei and those that provide the energy of nuclear fission. The speaker must explain his terms, often by analogy, and must give some idea of the orders of magnitude involved. Then he must explain the potency of neutrons in provoking nuclear changes, and show how in special circumstances a chain reaction may be maintained. Finally, he may say as little as he cares, or as much as he dares, about the technical processes of pile operation and bomb design.

Dr. Darrow does all this with skill, and enlivens it with wit; when it is expedient to sacrifice exactness for clarity, he says quite clearly that this is being done. The result is an attractive and honest simplification of the subject that must have given great pleasure, as well as much information, to the audience; it is certainly pleasant and instructive to read.

It is a pity, though, that Dr. Darrow should propagate the myth that the extraction of energy from nuclei depends upon a knowledge of Einstein's mass-energy relation. P. B. MOON

The Naturalism of Samuel Alexander

By John W. McCarthy. Pp. ix+111. (New York: King's Crown Press; London: Oxford University Press, 1948.) 14*s*. net.

THIS modest, but well-produced, book is another example of the good service provided by the King's Crown Press in making available sound learning at a reasonable cost without sacrificing anything essential. The author gives a most readable, and at the same time critical, account of Alexander's position, in particular his emphasis upon *nisus* (or urge) in all types of human activity. This comes out clearly in the chapter on the tertiary qualities (beauty, goodness, truth), and the connexion with levels of emergence is carefully explained.

An attempt to discuss value is perhaps less convincing; the author may well be right in his contention concerning the inadequacy of the instinctive life as such. But this is rather more a problem for 'applied sociology' than a basic defect of Alexander's philosophy. More serious by far, in the reviewer's opinion, is the *cul-de-sac* presented by leaving metaphysics 'stranded' without a liturgy, the result of an excessive realism in æsthetics. Dr. J. W. McCarthy's reaction to this seems admirable; perhaps he will develop it further.

F. I. G. RAWLINS

NEUTRON DIFFRACTION BY CRYSTALS*

By Dr. KATHLEEN LONSDALE, F.R.S.

IN considering the new technique of neutron diffraction by crystals it is necessary to discuss: (1) the properties of neutrons; (2) their sources, methods of observation and measurement; (3) their interaction with matter; (4) experimental methods; (5) results of experiments.

Properties of Neutrons

Neutrons are uncharged particles of approximately the same mass as the proton (hydrogen nucleus); actually they are a little heavier. Their linear dimensions are about 10^{-13} cm., only about one ten-thousandth of the size of the atoms in a crystal. They have spin and therefore a magnetic moment. They also have velocity and may usefully be described, therefore, in terms of their energy $mv^2/2$. A beam of neutrons of uniform velocity, that is, a mono-energetic beam, will be in equilibrium with matter at temperature $T°$ K., where $mv^2/2 = kT$ (k is Boltzmann's constant). In terms of the wave-theory, they will also have a wave-length $\lambda = h/mv$ (where h is Planck's constant) and a frequency $\nu = v/\lambda$. This wave may be interpreted in terms of the probability that neutrons of velocity v would be observed in a given place at a given time.

The range of neutron energies of practical importance for diffraction techniques is from 0·001 to 1,000 eV. The relationship between wave-length λ expressed in Angström units and energy E in electron-volts is $\lambda = 0{\cdot}285/\sqrt{E}$, and this range therefore corresponds to 9 to 0·009 A. The corresponding frequencies are of the order of 10^{13}/sec., the frequencies, in fact, of thermal vibrations in solids.

Sources of Neutrons

Neutrons were first obtained by the bombardment of light elements by α-particles from radium or polonium:

$$_4Be^9 + {}_2He^4 \rightarrow {}_6C^{12} + {}_0n^1$$
$$_5B^{11} + {}_2He^4 \rightarrow {}_7N^{14} + {}_0n^1.$$

Radium–beryllium sources were used in early diffraction experiments, with heavy shielding by paraffin, lead and cadmium being required to prevent neutrons and γ-radiation from escaping in unwanted directions.

Neutrons may also be obtained by bombardment of a light element with deuterons from a cyclotron. Either beryllium, or deuterium from heavy ice or heavy paraffin, may be used, the latter giving a more homogeneous beam:

$$_4Be^9 + {}_1H^2 \rightarrow {}_5B^{10} + {}_0n^1$$
$$_1H^2 + {}_1H^2 \rightarrow {}_2He^3 + {}_0n^1.$$

The yield of neutrons per bombarding particle using any of the above methods is, however, extremely low.

The most effective source of neutrons is the atomic pile, but fission neutrons from uranium-235 or plutonium-239 are much too fast for diffraction experiments and must be slowed down by repeated collisions with light nuclei. The loss of energy of neutrons is greatest on collision with protons, but hydrogenous material is not the best moderator, because capture of neutrons takes place rather too easily: $_1H^1 + {}_0n^1 \rightarrow {}_1H^2 + \gamma$-radiation. Better moderators are heavy water or graphite, in which the probability of neutron capture (the capture 'cross-section') is very small. When the energy of the neutrons is reduced to such a value that they are in thermal equilibrium with the atoms of the moderator, they are allowed to emerge from the pile as a collimated beam. They are not, however, mono-energetic; there is an approximately Maxwellian energy distribution. If the neutron spectrum is considered as a whole, having a mean energy $mv^2/2 = 3/2\ kT$, then since the corresponding wave-length

$$\lambda_{mean} = \frac{h}{m\sqrt{v^2}} = \frac{h}{\sqrt{3mkT}},$$

it follows that thermal neutrons in equilibrium with matter at 100° C. will have a mean wave-length 1·33 A., or at 0° C., 1·55 A. The corresponding peak wave-lengths will be $\sqrt{3/2}$ times greater, that is, 1·63 A. (100° C.) and 1·90 A. (0° C.) respectively[1]. These are approximately the same wave-lengths as those that are used in X-ray diffraction techniques.

Since there is no source of neutrons giving a monochromatic beam, such as would correspond to, say, $K\alpha$ characteristic X-rays, the range of neutron energies used must be limited. This can be done either by means of a mechanical velocity selector[2] or, for a medium range and better resolution, by crystal reflexion. The narrowness of the energy band isolated by reflexion is determined by crystal perfection and degree of collimation. It is not, however, possible to collimate the neutron beam very sharply, because of loss of intensity. After monochromatization from a wedge-shaped sodium chloride crystal, cut at 6·5° with the (200) plane, the neutron beam used at the Clinton Laboratories, Oak Ridge, has a cross-section $\frac{3}{4}$ in. × 1 in., a wave-length 1·06 A., and an intensity of 2×10^6 counts per minute[3].

Methods of Detection and Counting of Neutrons

Although neutrons themselves, being uncharged, give no track in a cloud chamber, they can be detected by means of the V-shaped tracks that occur when they are captured by certain nuclei; for example, $_7N^{14} + {}_0n^1 \rightarrow {}_5B^{11} + {}_2He^4$. The range of the recoil particles may be used to give a measure of the original neutron energy. Such a method could obviously not be used for crystal diffraction measurements. For early work in this field an ionization chamber lined with a compound containing lithium or boron, or filled with boron trifluoride gas, was used[4]:

$$_3Li^6 + {}_0n^1 \rightarrow {}_1H^3 + {}_2He^4;\ {}_1H^3 \rightarrow {}_2He^3 + {}_{-1}e^0$$
$$_5B^{10} + {}_0n^1 \rightarrow {}_3Li^7 + {}_2He^4.$$

Modern ionization methods use boron trifluoride enriched in the boron-10 isotope, with a Geiger–Müller proportional counter, readings being made over 4-min. time intervals at each counter position, with and without a cadmium shutter in position[3]. Since, in general, the intensity is not greatly in excess of the general cosmic background, repeated readings are frequently necessary, and automatic methods of recording are employed[5].

* Based on a Friday Evening Discourse at the Royal Institution, delivered on March 18.

For photographic techniques, the use of a secondary ionizing agent is essential, since neutrons themselves scarcely affect the film emulsion. Two methods are possible: the detecting agent, which could be a light, absorbing atom such as boron, lithium or nitrogen, might be incorporated in the actual emulsion; or (and this method is in actual use at Oak Ridge) a sheet of, say, indium may be placed, like a fluorescent screen, in front of the photographic film, which then records the induced β-ray activity:

$$_{49}\mathrm{In}^{115} + {}_{0}n^{1} \rightarrow {}_{49}\mathrm{In}^{116} \rightarrow {}_{50}\mathrm{Sn}^{116} + {}_{-1}e^{0}.$$

Laue photographs made in this way, using the whole neutron spectrum from the atomic pile, have required exposure times of the order of 10 hours with a crystal-to-film distance of 6·4 cm. and a beam 6 mm. in diameter[6].

Interaction of Neutrons with Matter

If N atomic nuclei per c.c. are arranged in a uniform neutron beam in which n neutrons cross 1 cm.^{2} per sec., then the total number of neutrons captured and scattered per c.c. in time t sec. will be $nNt\sigma_t$, where σ_t is the 'total cross-section' of the atomic nucleus in question. It will depend on the capture cross-section (σ_c) and scattering cross-section (σ_s) respectively, the latter being, in general, much the larger effect. All these nuclear 'cross-sections' are measured in units of 10^{-24} cm.^{2}, this unit being known as the *barn*. (The name is said to have originated in a remark of Prof. Fermi that a target of the size of 10^{-24} cm.^{2} was as big as a barn-door.)

Since both capture (true absorption) and scattering (coherent or Bragg diffraction effects, and incoherent or background effects) are dependent on neutron energy, monochromatic beams are used to make quantitative measurements whenever this is possible. For low-velocity neutrons, σ_c should, theoretically, vary inversely with the velocity v; experimentally, however, this holds only for a few atoms (for example, silver and boron). High absorption values usually correspond to capture by one isotope only.

Absorption effects introduce a big difference between X-ray, electron and neutron diffraction phenomena. For X-rays, absorption is always greater than scattering, and although interference effects introduce the additional absorption effects known as 'extinction', it is possible to estimate and correct for both absorption and extinction in single crystals and hence to obtain a measure of the true scattering power of the substance, which depends, among other things, on the crystalline structure. For electrons, absorption is such a large effect that only diffraction from films or surfaces can be observed. For neutron diffraction, on the other hand, true absorption may be negligible compared with scattering, and the intensity of diffraction from a single crystal will in that case be more dependent upon the thickness and mosaic spread of the crystal (that is, upon extinction) than upon its structure[1]. For purposes of structure determination, therefore, or for the determination of scattering cross-sections, the use of powders is preferable to that of single crystals, except in special cases[7].

An electromagnetic wave having its vibrations normal to the plane of incidence is scattered by a free particle of charge e and mass m with an amplitude e^2/mc^2, which is obviously much larger for an electron than for a nucleus. The scattering of X-rays, therefore, is almost entirely by the atomic electron cloud, scattering amplitudes for atoms being of the order of 10^{-12} cm. and increasing steadily as the atomic number increases. Since the electron cloud is extended in space, interference effects within the atom will cause a dependence of f_e, the atomic scattering factor for X-rays, upon $\sin\theta/\lambda$ and upon electronic distribution. The marked falling-off of f_e at large angles is the main factor in causing convergence of the series used in Fourier analysis and Patterson analysis, without which *direct* methods of crystal structure determination would be impossible. X-ray scattering will differ for an atom and its ions and may be used, in favourable cases, to determine the state of ionization.

The mechanism of neutron scattering is different. Neutrons, being massive uncharged particles, are scattered only by the nuclei, and not by electrons, if we ignore, for the moment, possible effects due to magnetic fields interacting with the neutron magnetic moment. (These will, in any event, be incoherent and will occur to an appreciable extent only in ferromagnetics or strong paramagnetics[8].) Unlike X-rays, neutrons are not polarized on scattering. (Again this is only true if the effects of magnetic fields on the neutron spin states may be ignored, a condition which is usually satisfied[9,10].) Since the scattering nuclei are effectively points, there is no falling-off of neutron scattering amplitudes with $\sin\theta/\lambda$, except in respect of thermal vibration. The reduction in scattering cross-sections with increasing temperature follows the usual Debye–Waller law. This was predicted theoretically[11] and has been proved experimentally[4]. This lack of adequate convergence of intensity values at high angles of deflexion means, unfortunately, that only 'trial and error' methods of structure analysis are possible. If f is the amplitude of the scattered neutron 'wave' at unit distance from the scattering nucleus and for unit intensity of the incident beam, then the amplitude at distance r will be f/r, and the total energy per unit beam scattered per nucleus, that is, the scattering cross-section, is $\sigma_s = 4\pi r^2 . f^2/r^2 = 4\pi f^2$.

The accompanying table shows that $f = \sqrt{\sigma_s/4\pi}$ for neutrons is comparable in value with $f_e e^2/mc^2$ for X-rays for atoms of atomic number about 3 to 11. The values of scattering amplitudes for neutrons are, however, much larger for very light atoms, and much smaller for heavy atoms, than those for X-rays. Subject to certain experimental difficulties, therefore, neutron diffraction techniques provide a means of determining the positions of light atoms in structures where they are combined with heavy atoms (for example, hydrides, deuterides, organic compounds, interstitial alloys, etc.), a problem which is always difficult, and sometimes impossible, to tackle using X-rays only. There is, as yet, no known method of calculating the amplitudes of the neutron waves scattered by the individual nuclei, since these depend on unknown forces; hence the values given in the table are empirical and are mostly subject to a considerable degree of possible experimental error. It will be seen that the data given refer to *coherent* scattering. In general, any scattering substance is characterized by three different scattering cross-sections for neutrons. Suppose that a_1, a_2, etc., are the scattering amplitudes in the free state (for example, gas) and f_1, f_2, etc., those in the bound state (for example, liquid or solid) for atoms of kinds 1, 2, etc., which are present in relative abundance p_1, p_2, etc.

Absorption cross-sections and scattering amplitudes of a selection of atoms, for X-rays and neutrons respectively. Absorption cross-sections in 10^{-24} cm.^{2}, scattering amplitudes in 10^{-12} cm.

Atomic number and element	Atomic absorption coefficients for X-rays, $\lambda = 1{\cdot}54$ A.	Absorption cross-sections for neutrons, $\lambda = 1{\cdot}8$ A.	Coherent scattering amplitudes for X-rays at $\frac{\sin\theta}{\lambda} = 0{\cdot}5$	Coherent scattering amplitudes for neutrons*
1 H parallel spins			0·02	+0·52
1 H anti-parallel			0·02	−2·37
1 H$^+$			0	−0·40
1 H$^-$			0·04	−0·40
1 H		0·313	0·02	−0·40
1 D		<0·00065	0·02	+0·63
3 Li^6		870	0·28	+0·7
3 Li^7		0·03	0·28	−0·25
3 Li (92% Li^7)		67·4	0·28	−0·18
6 C	109	0·0045	0·48	+0·64
8 O	336	<0·0016	0·62	+0·58
9 F	547	0·0094	0·75	~+0·6
11 Na	1,170	0·5	1·14	+0·35
13 Al	2,170	0·21	1·55	+0·35
17 Cl	6,040	33	2·05	+0·99
22 Ti	16,160	6	2·68	−0·38
23 V	19,100	5	2·85	< 0·09
25 Mn	25,700	12·8	3·13	−0·33
26 Fe	29,800	2·4	3·27	+0·91
27 Co	34,300	34	3·41	+0·37
28 Ni^{58}		4·3		+1·44
28 Ni^{60}		2·7		+0·28
28 Ni^{62}	4,750	14·8	3·58	
28 Ni^{64}		2·6		
28 Ni		4·6		+1·04
29 Cu	5,620	3·4	3·75	+0·76
35 Br	12,020	7·4	4·71	+0·67
40 Zr	21,200	0·4	5·56	+0·625
47 Ag	39,600	57	6·71	+0·61
48 Cd	43,400	2410		
49 In	47,600	187		
50 Sn	51,600	0·65		+0·61
64 Gd	122,000	47,500		
79 Au	69,500	95	12·36	+0·77
82 Pb	82,200	0·2	12·90	+0·96
83 Bi	86,800	0·015		0·90
92 U	138,000	2		

* Values kindly communicated by Dr. C. G. Shull

Then $\sigma_{free} = 4\pi(p_1a_1^2 + p_2a_2^2 + \ldots)$

$\sigma_{bound} = 4\pi(p_1f_1^2 + p_2f_2^2 + \ldots)$

and $f = \frac{A+1}{A}a$, where A is the atomic mass, and $\frac{A}{A+1}$ the reduced mass of atom + neutron. For hydrogen, $\sigma_{bound} = 4\sigma_{free}$; but the difference rapidly becomes negligible for heavy atoms. Now if the atoms are scattering not independently, but *coherently*, then the amplitudes of the scattered waves must be added vectorially, *before* squaring to give the intensity. Therefore

$$\sigma_{coherent} = 4\pi(p_1f_1 + p_2f_2 \ldots)^2.$$

The difference ($\sigma_{bound} - \sigma_{coherent}$) represents the incoherent background scattering. Various effects tend to increase the background and reduce the intensities of the Bragg spectra. Among these are, or may be:

(1) Thermal vibration: as in the case of X-rays, this will involve consideration of the kinds and arrangement of atoms in the structure, and can only be *simply* allowed for in elements of cubic structure.

(2) Multiple scattering. This is important on account of the small value of the true absorption, and causes an appreciable diffuse scattering at small angles, where temperature scattering would be small[4].

(3) Magnetic scattering, mentioned previously, which is, however, only important for special substances and for long wave-lengths[8].

(4) Isotope incoherence, due to the *random* arrangement in the structure of isotopes of different scattering amplitudes. Separation of pure isotopes has given the separate amplitudes in some instances.

(5) Spin incoherence, due to the random existence of parallel and anti-parallel spin when the scattering atom has spin and therefore can have two spin states relative to the neutron. This is particularly important for hydrogen, where it reduces the value of $\sigma_{coherent}$ to 2·0 barns, as compared with a value of 80 barns for σ_{bound}[12]. This results in a very large diffuse background for neutron spectra from hydrogenous substances, and greatly increases the experimental difficulties of determination of structure for such compounds. The spin incoherence for deuterium is relatively small, and therefore it is better to carry out structure investigations on deuterated compounds when these can be prepared in a pure state.

(6) Diffuse scattering may also be caused by an actual disordering of the structure, as, for example, in the case of quenched alloys[13]. This effect will operate also for X-ray scattering, whereas those due to the existence of spin or of isotopes would not do so.

One very striking result shown in the table is that some neutron scattering amplitudes are negative. By convention, this means that the phase shift of the total scattered wave relative to the incident wave is 0° instead of 180°, as it is for X-rays and for most neutron scattering[14]. A zero phase shift occurs, in fact, only when the neutron–nucleus interaction is in the near vicinity of a resonance level; it is therefore not common. The positive and negative values of the scattering amplitudes for the two spin states of hydrogen have been found not only from crystal measurements[12] (using sodium hydride) but also from neutron scattering by ortho- and para-hydrogen gas[15], the agreement found being excellent[8].

Experimental Methods and Results

Experiments, using radium + beryllium as a neutron source, and without monochromatization, were carried out as early as 1936–37; and these demonstrated the existence of diffraction effects in crystals, but without giving reliable quantitative data[4,16].

Since 1945, the atomic piles at Argonne and at Oak Ridge have provided intense neutron beams with which many measurements have been made using both single crystals[17,14] and powdered specimens[5]. In 1946, Fermi, Zinn and Marshall measured the critical angle of total reflexion of a beam of neutrons from various mirror surfaces. The index of refraction for neutrons is given by $n = 1 - \lambda^2 Nf/2\pi$, where λ is neutron wave-length, N the density of atoms in the reflecting surface, f the scattering amplitude with its proper sign. n is only less than 1 if f is positive; this, then, is the condition that total reflexion can occur. As with X-rays, $(n - 1)$ is of the order of 10^{-6} and the critical angle is of the order of 10′. Experiments of this kind showed that carbon, beryllium, iron, nickel, copper and zinc scatter neutrons with a positive scattering amplitude[18].

Subsequent investigations of the scattering cross-sections of gaseous carbon dioxide, nitric oxide and carbon tetrafluoride, for very slow neutrons, showed that the observed interference effects could only be explained if oxygen, nitrogen and fluorine also had positive scattering amplitudes[14].

Small-angle scattering of neutrons by lampblack and other finely powdered substances has been

observed quite recently, using neutrons of very low energies ($< 0{\cdot}003$ eV.) obtained by means of the mechanical velocity selector[19]. This is analogous to the comparable X-ray effect. Another type of small-angle scattering, for which there is no X-ray equivalent, is that obtained in unmagnetized iron (disappearing in moderate magnetic fields) and due presumably to magnetic refraction of neutrons at domain boundaries[20].

The two main groups of experiments on the scattering of neutrons by crystals have involved:

(1) The measurement of coherent diffracted beams and of the incoherent diffuse background, for a given wave-length[17,5], as a function of diffraction angle.

(2) The measurement of the intensity loss in the direct beam on transmission through the scattering material, as a function of varying neutron energy[21].

The first method is essentially similar to the corresponding X-ray techniques. For the powder method the same diffraction formula applies, but with the polarization factor omitted:

$$\frac{P_{hkl}}{P_0} = \frac{\lambda^3 l}{4\pi r}\,\frac{t\rho'}{\rho}\,.\,\frac{\exp(-\mu t\sec\theta)}{\sin^2 2\theta}\,p_{hkl}\,\frac{F_{hkl}^2}{V^2},$$

where P_{hkl} is the integrated power in an (hkl) reflexion, as measured by a counter slit, height l at distance r from the specimen, P_0 the primary beam power, ρ' the apparent powder density, ρ the true crystal density, t the specimen thickness, p_{hkl} the multiplicity value, V the unit cell volume and F_{hkl} the Bragg scattering amplitude per unit solid angle per unit cell. F_{hkl} therefore contains the geometrical structure factor, the nuclear scattering amplitudes f_1, f_2, etc., and the appropriate Debye–Waller temperature factors. The absorption factor $\exp(-\mu t\sec\theta)$ will be approximately unity if absorption is negligible.

In order to determine f_1, f_2, etc., which was the primary object of the first experiments, crystals of known structure were used and values of $P_0F_{hkl}^2$ determined for all possible planes. For crystals of the elements it was found that the application of an appropriate temperature factor did, in fact, give a constant value of $P_0f_0^2$ after correction for structure[5].

$F_{hkl} = \Sigma f_0 \exp(-W)\exp\{-2\pi i(hx + ky + lz)\}$ (atoms at x, y, z; W, temperature factor).

With crystals of binary compounds, consideration had to be given to the possibility that the two atoms in the formula molecule might be scattering with opposite signs. A study of crystals of the sodium chloride type of structure would give spectra as follows: (1) planes with 'mixed indices' would not reflect; (2) planes with 'all-even' indices would reflect with intensity proportional to $(A + B)^2$; (3) planes with 'all-odd' indices would reflect with intensity proportional to $(A - B)^2$.

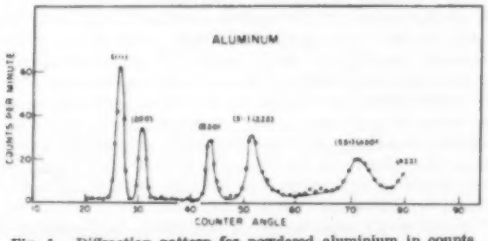

Fig. 1. Diffraction pattern for powdered aluminium in counts per minute versus counter angle (2θ) (E. O. Wollan and C. G. Shull, Oak Ridge)

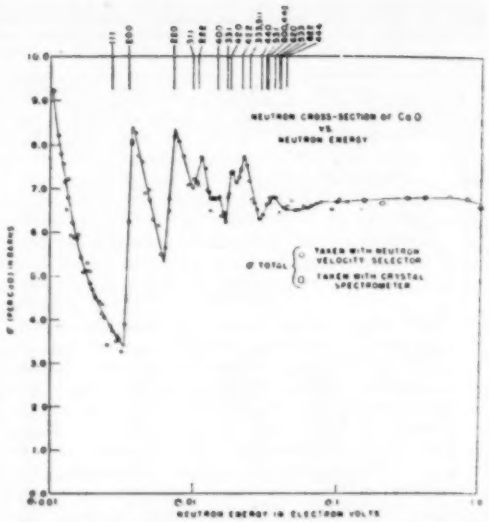
NEUTRON CROSS-SECTION OF CaO VS. NEUTRON ENERGY
σ TOTAL
TAKEN WITH NEUTRON VELOCITY SELECTOR
TAKEN WITH CRYSTAL SPECTROMETER
σ INCOHERENT
NEUTRON ENERGY IN ELECTRON VOLTS

Fig. 2. Transmission spectrum for powdered calcium oxide, in total cross-section per molecule in barns versus neutron energy in electron-volts (L. Winsberg, D. Meneghetti and S. S. Sidhu, Argonne)

If, therefore, the 200, 220 planes were strong and the 111, 113 weak, A and B must be scattering with amplitudes of the same sign. This was found to be the case for sodium fluoride, chloride, bromide and deuteride. Since f for fluorine was known to be positive, it followed that all the rest were also positive. In the case of lithium fluoride, manganese oxide and sodium hydride, however, 111, 113, 331 were strong and 200, 220, etc., weak, showing that lithium, manganese and hydrogen must have negative scattering amplitudes. It was not, in fact, certain to begin with that sodium hydride and deuteride were of the sodium chloride type; but intensity considerations were able to eliminate all other possibilities, taking both possible combinations of signs into consideration.

Determination of the *absolute* values of the scattering amplitudes f_1, f_2, etc., required a knowledge of P_0; and since this was large (2×10^6 counts/min. in the whole area of the neutron beam after monochromatization) a direct determination in each experiment would have been difficult. Shull and Wollan[5] therefore chose diamond for use as a standard, and determined the absolute value of the coherent scattering cross-section for carbon in diamond by the transmission method (2), now to be described[21].

If $R(a)$ and $R(0)$ are the counting-rates, corrected for background, respectively with and without the powdered scattering sample in the neutron beam, and if N is the number of atoms/cm.^{3} of the irradiated surface, then the total cross-section of the scattering nuclei will be given by

$$\sigma_t = \frac{\log R(0) - \log R(a)}{\Delta}$$

Provided that true absorption is negligible, and supposing that the substance contains only one kind of atom, and that the scattering is free from spin and isotopic incoherence, then

$$\sigma_t = \frac{\lambda^2}{8V}\sum_{hkl} p_{hkl}\,d_{hkl}\,.\,c_s\,.\,R_{hkl},$$

where R_{hkl} includes the geometrical structure factor and the Debye–Waller temperature factor. d_{hkl} is the interplanar spacing, and the summation is taken over all planes which satisfy the condition that $\lambda < 2d$. Now carbon-12 is spin-free and carbon-13 is only present to the extent of 1·1 per cent, and moreover the true absorption is extremely low; a measurement of σ_t will therefore give σ_s to a good degree of approximation for diamond.

Since all wave-lengths greater than $2d_{max.}$, where $d_{max.}$ is the largest effective interplanar spacing in the crystal, will be transmitted without loss due to coherent scattering, it follows that one method of obtaining an approximately monochromatic beam of *long* wave-length neutrons will be to filter through a considerable thickness of some non-absorbing material, free from spin or isotopes; beryllium oxide satisfies the conditions very well.

For thinner specimens and for values of $\lambda < 2d_{max.}$ the transmission will obviously vary discontinuously as the neutron energy is varied, and will, in fact, show peak values as one after another of the crystal planes is able to take part in the scattering, the height of the peaks varying according to the crystal structure and, in the case of compounds, according to the relative scattering amplitudes of the atoms (Fig. 2). Even if there is absorption and a certain amount of incoherence, the coherent scattering peaks will still be present. Investigations at the Argonne laboratory[23], made over a range of 0·001–1·0 eV. neutron energies, obtained by use of the rotating shutter 'time of flight' selector (0·001–0·2 eV.) and the crystal spectrometer (0·1–1·0 eV.) in conjunction with the neutron beam from the heavy-water (D_2O) pile, have shown that characteristic 'transmission versus energy' spectra are found for face-centred cubic, body-centred cubic and close-packed hexagonal structures. An experiment using titanium-carbide showed that titanium atoms must scatter with a negative scattering amplitude. The absolute values of the coherent cross-sections obtained by the use of this method do not at present, however, agree particularly well with those obtained by method (1), which is probably the more reliable for this purpose. The transmission does, of course, vary markedly if preferred orientation exists in the powder[23], through cold-working in the case of a metal specimen, for example, and may be used to determine such orientation effects in large specimens.

A study of the table of absorption cross-sections and scattering amplitudes already given shows that the transition and neighbouring elements, which have closely similar scattering amplitudes for X-rays, have widely different scattering amplitudes for neutrons. Neutron diffraction may therefore be used to study disorder → order phenomena in such alloys as FeCo and Ni_3Mn, where X-rays would be almost useless[24]. The situation is reversed, however, for Cu_3Au, where the scattering amplitudes differ widely and those for neutrons are almost identical.

Another structural problem studied by method (1), and reported by Shull at the Harvard Crystallographic Congress, 1948, was that of the location of the deuterium atoms in heavy ice. (Ordinary ice was avoided because of the intense spin incoherence for hydrogen, previously referred to.) Even although the neutron diffraction spectra are not yet well resolved, the results show unequivocably that while ice has a molecular, and not an ionic structure, only the oxygen atoms occupy ordered positions. The orientation of the molecules is disordered in such a way as to give the effect of four half-deuterium atoms tetrahedrally arranged, along O—O bonds, around each oxygen atom. The data cannot decide, however, between a static and a dynamic type of disorder.

It seems probable that even when neutron diffraction techniques have improved considerably, the best work will be done by a combination of X-ray and neutron data. The X-ray methods of direct analysis can locate the heavier atoms with considerable accuracy, while subsequent use of information from neutron scattering will give the positions of the lighter nuclei.

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DIABETOGENIC ACTION OF PURE ANTERIOR PITUITARY GROWTH HORMONE

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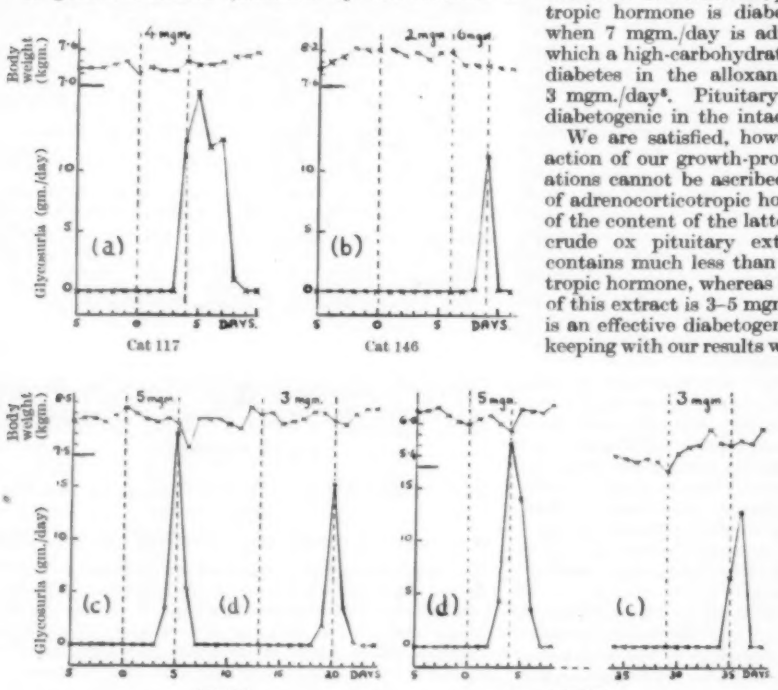
IN this laboratory, investigations designed to purify the diabetogenic principle of ox anterior pituitary tissue, the daily administration of which to the intact dog or cat induces a condition of diabetes mellitus, have been in progress for some time[1–3]. Methods involving precipitation in the presence or absence of neutral salts have yielded a potent preparation capable of inducing the appearance of glycosuria in a normal intact cat when administered in a dose of 4 mgm. protein/day (approximately 0·1 mgm. protein N/kgm. body weight/day) over a period of four days (graph *a*). We have found similar diabetogenic activity to be exhibited both by purified

growth hormone prepared in our laboratory by the method of Li, Evans and Simpson[4] and by the crystalline growth hormone obtained by the ethanol-precipitation method of Wilhelmi, Fishman and Russell[5] (see graph *b*). We have also had the opportunity of testing, in the intact adult cat, the diabetogenic activity of growth hormone prepared according to the method of Li *et al.*[4] by Dr. C. H. Li of the Institute of Experimental Biology, University of California (to whom we are grateful for his generous gift), and also of crystalline growth hormone prepared in the laboratories of Armour and Co., Chicago, by the method of Wilhelmi *et al.*[5]. For the gift of the latter preparation we are indebted to Dr. A. E. Wilhelmi, of the Department of Physiological Chemistry, Yale University, and to Dr. I. M. Bunding, of Armour and Co., Chicago. Both preparations were highly diabetogenic in the adult intact cat (graphs *c* and *d*), and, doubtless, similar activity can be demonstrated in the intact adult dog, since in our experience the cat and the dog are strictly comparable test animals in such experiments. It will be seen from the graphs that under the conditions of our experiments treatment with growth hormone caused little or no significant change in the body-weight of adult intact cats.

Recently, Milman and Russell[6] have shown that the administration, to fasting, partially depancreatized or alloxan-diabetic rats, of highly purified preparations of growth hormone (obtained by the method of Wilhelmi *et al.*[5]) in a dose of 3–5 mgm. protein/100 gm. of body-weight, induces a substantial rise of blood-sugar level. In our laboratory we have never succeeded in inducing glycosuria in the intact rat by the administration of enormous doses of growth-promoting ox pituitary extracts and, moreover, we have been unable, in many instances, to induce even an exacerbation of an existing diabetic condition when partially depancreatized or alloxan-diabetic rats of our experimental strains (albino and black-and-white) are treated daily with a dose of ox anterior pituitary extract which is highly diabetogenic in the intact adult cat, and which is comparable in growth-hormone activity with that employed in the experiments of Milman and Russell[6]. It may be noted that in our experiments the daily dose of extract which usually failed to increase the severity of an existing diabetes in the rat was, per kgm. of body-weight, 50–100 times that active in inducing diabetes in the normal intact cat and 50–100 times that effective in stimulating 50 per cent of the maximum possible growth-rate in the adult intact female rat. Bennett and Li have also found no significant effect on glycosuria when 3 mgm./day of growth hormone is administered daily for 5–6 days to alloxan-diabetic rats weighing about 200 gm. It is therefore clear that the rat, either normal or diabetic, is a most unreliable and insensitive test animal for the diabetogenic or diabetes-intensifying action of growth hormone. Nevertheless, pure pituitary adrenocorticotropic hormone is diabetogenic in the intact rat when 7 mgm./day is administered to an animal to which a high-carbohydrate diet is fed[7], and intensifies diabetes in the alloxan-diabetic rat in a dose of 3 mgm./day[8]. Pituitary adrenocorticotropin is also diabetogenic in the intact human being[9].

We are satisfied, however, that the diabetogenic action of our growth-promoting ox-pituitary preparations cannot be ascribed primarily to their content of adrenocorticotropic hormone. For example, assay of the content of the latter substance in our standard crude ox pituitary extract indicates that 1 ml. contains much less than 0·1 mgm. of adrenocorticotropic hormone, whereas the growth-hormone content of this extract is 3–5 mgm./ml. Of this extract, 1 ml. is an effective diabetogenic dose in the intact cat, in keeping with our results with the purified hormone (see graphs). Although we have not assayed our preparations of the purified growth hormone from ox pituitary tissue for adrenocorticotropic activity, it is certain that they cannot be so grossly contaminated with adrenocorticotropic hormone as to account for their diabetogenic activity on this basis alone.

It cannot be completely excluded that the diabetogenic activity of pure growth hormone and of pure adrenocorticotropin may be due in each case to contamination by a third substance—a diabetogenic pituitary principle not possessing any other obvious activity. Nevertheless, we believe this to be unlikely



Influence of daily injections of preparations of the anterior pituitary growth hormone on the body-weight and glycosuria of intact adult cats. In each experiment the vertical dotted lines indicate the first and last days of a series of daily subcutaneous injections of a solution of the hormone; the daily dose is shown at the top of each diagram

(*a*) 'Saline supernatant' fraction CA 35·112 prepared by us according to the method of Reid and Young

(*b*) Crystalline growth hormone prepared by us according to the method of Wilhelmi *et al.*

(*c*) Crystalline growth hormone prepared in the laboratories of Armour and Co. according to the method of Wilhelmi *et al.*

(*d*) Pure amorphous growth hormone prepared by Dr. C. H. Li according to the method of Li *et al.*

both on chemical and on physiological grounds. The growth hormone prepared according to the method of Li *et al.*[4] is electrophoretically homogeneous, and, indeed, both growth hormone and adrenocorticotropic hormone have been intensively studied by Dr. C. H. Li[10], who has characterized them as single proteins as closely as is possible with the methods at present available. It therefore seems improbable that significant contamination of two such different proteins by a common impurity has completely escaped detection so far.

In 1940, Marks and Young[11] found that under certain conditions a crude ox anterior pituitary extract could lose ability to induce diabetes in the intact dog without diminution in its capacity to induce growth in the intact adult female rat, and recently we have essentially confirmed and extended these findings. Although their interpretation is still uncertain, in our view these observations do not constitute evidence against the idea that the diabetogenic activity of pure growth hormone is a property of the protein-hormone itself.

The possibility that the diabetogenic or diabetes-intensifying activity of ox anterior pituitary extracts is associated with growth-promoting activity has been recognized for some time[12–15]. Indeed, such an idea was immanent in the first observation of the diabetogenic action of anterior pituitary extract in the intact animal, made in the laboratory of H. M. Evans in 1932, where diabetes was observed in a proportion of grown puppies which for some months had been given daily injections of a growth-promoting alkaline extract of ox anterior pituitary tissue[16]. These experiments were repeated by Young[17], who found that daily injection of an ox anterior-lobe extract which was highly diabetogenic in the intact adult dog induced an enhancement of growth-rate without glycosuria in the growing puppy, although after some months of treatment a proportion of the treated puppies did become diabetic. We have since obtained comparable results with kittens and cats[18].

In our own laboratory the only species we have found consistently to exhibit diabetes when growth-promoting ox anterior pituitary extracts are injected daily into the intact normal animal are the adult dog, cat and ferret. The adult rabbit sometimes, but the intact rat, mouse and guinea pig never, exhibit diabetes under these conditions in our experience[19].

It is not unreasonable to assume that the diabetogenic action of growth hormone is the pathological outcome, exhibited in a limited number of species under certain conditions, of the excessive stimulation of those processes which may normally lead to an enhancement of growth-rate. In 1939, Young[1], discussing the possibility that growth hormone and the pituitary diabetogenic substance were identical, wrote, "The evidence . . . is compatible with such an idea, if it be assumed that integrity of pancreatic function is essential for the nitrogen retention required for a period of pituitary-stimulated growth. If the pancreas is unable to sustain the demand thus imposed a diabetic condition might develop." This view has been supported by the evidence accumulated since 1939, and it is interesting to note that in their recent publication Milman and Russell[6] write "[Our] results suggest that in the normal rat, the administration of growth hormone may provoke secretion of extra insulin. In the animal lacking sufficient islet tissue, hyperglycæmic or contra-insulin effects of the growth hormone are seen instead." As Young[15] has suggested, diabetes induced by growth-stimulating pituitary extract "probably represents the pathological result of an excessive stimulation of these processes (inhibition of oxidation of carbohydrate with enhancement of protein storage and of fat combustion) which, under more physiological conditions, lead to such deposition of new tissue as is associated with growth". The identity of the growth hormone with our diabetogenic substance is therefore completely consonant with our views upon the general action of growth hormone.

The diabetogenic action of pituitary adrenocorticotropic hormone may also be regarded as the pathological outcome of the excessive stimulation of processes of physiological significance, though here the mechanism of action is different from, and in some ways contrary to, that of the growth hormone. Thus, in our view the diabetogenic principle of the anterior pituitary gland is complex in nature, consisting of at least the growth and adrenocorticotropic hormones. Since ox pituitary extract is rich in growth hormone and poor in adrenocorticotropic hormone, and since, moreover, most of the experiments concerning the diabetogenic action of pituitary extracts have been carried out with material prepared from ox tissue, it is very probable that, apart from those investigations in which purified adrenocorticotropic hormone was used, the successful demonstration of anterior pituitary diabetogenesis has hitherto depended primarily upon the presence of growth hormone in the pituitary extracts employed.

We conclude, therefore, that pure growth hormone is diabetogenic in the intact adult cat. Diabetes induced by growth hormone is believed to represent a pathological outcome of the excessive stimulation of a physiological process. The same is probably true of the diabetes induced by treatment with pituitary adrenocorticotropic hormone. The diabetogenic principle of the anterior pituitary gland must be complex in nature, consisting of at least the growth and adrenocorticotropic hormones.

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VITAMIN A AND CAROTENE

ALTHOUGH much had been written and much had been done, nevertheless neither the Medical Research Council in Great Britain nor the National Research Council in the United States of America was in a position to give any definite answer when, at the beginning of the War, their respective Governments asked for information about the amounts of certain nutrients required by the human body.

In the United States, the National Research Council appraised the literature on the subject and formulated tentative dietary allowances. The figures thus set out in 1943 [1] have already been revised twice and will undoubtedly be revised further as more exact knowledge is acquired. In the meantime, however, they have been, and are being, widely misapplied by economists, administrators and others whose understanding of nutrition is, at the best, superficial [2]; they are also frequently misused by people who should know better. It is stated in the preamble to the 1945 revised version that "The term Recommended Allowances rather than Standards was adopted by the Board to avoid any implication of finality"—but they seem to have reckoned without human nature.

The folly of judging the adequacy of supply of a nutrient solely on the basis of its level in the diet is certainly brought out very clearly in a recent report of the Medical Research Council* on "Vitamin A Requirements of Human Adults"; for, with carotene, the degree to which it is absorbed varies to such an extent that, for the few foods tested, "the values for the daily requirement ranged from 4,000 to 12,000 I.U.".

The intention was to give a group of volunteers "a diet virtually devoid of vitamin A and carotene until unmistakable signs of deficiency appeared, and then to determine what dose of vitamin A or carotene was needed to ensure recovery to normal". The report states that "The experiment began in July 1942 and was expected to be complete in six to eight months. In fact it lasted two years and even at the end not all the original expectations had been realised."

Admittedly, vitamin A presents particular difficulties in view of the fact that it is normally obtained partly in the preformed state and partly as a precursor. In the words of the report, "the problem is one in which the human individuals and the different foods offered to them are capable of combining in a pattern so complex that it is difficult to formulate a standard value for the requirement of vitamin A, and almost impossible to deduce accurately from dietary surveys the effective intake of carotene". But I am inclined to think that, if equally detailed studies were made of other nutrients, a good many similar complications might be found to apply.

Perhaps the most unexpected findings in the present instance were "the prolonged delay before the onset of nutritional changes" (eight months of deprivation produced no discernible indication of deficiency), and the fact that some of the abnormalities commonly looked for as signs of vitamin A deficiency (for example, follicular hyperkeratosis) "were either absent or equally present in the deprived and the non-deprived or present in the same subjects both before and after depletion". Defective night-vision, with a raised rod-threshold and prolonged cone-rod transition-time, and a lowering of the plasma level of vitamin A proved to be the first definite signs of deficiency. The Committee is, however, careful to point out that the observations were made on young adults with good liver reserves, receiving a diet adequate in all other respects; where there has been chronic deprivation over a period of many years or where other dietary essentials are also lacking, the clinical picture may well be different.

In an experiment lasting so long and with so many facets under observation, the amount of documentary detail amassed must have made the task of editing the report a particularly onerous one. Some degree of selection and condensation was essential; but the report as published still contains a wealth of detail on the techniques used and the results obtained, and it is stated that all the detailed results of the various special investigations which were undertaken are available for consultation.

The report is divided into three parts: (1) concise account of the experiment; (2) elaboration of special aspects (for example, comparison of Wald's and Craik's adaptometers, effect of consumption of alcohol on capacity for dark adaptation and plasma values for vitamin A, a study of the normal value for the vitamin A and carotenoid content of human blood plasma); and (3) details of the evidence (including particulars and management of the volunteers, and summaries of the reports on the slit-lamp examination of the eye, audiometry, etc.).

Naturally, since dark adaptation and plasma-level of vitamin A proved to be the most useful criteria, most space is devoted to the methods and results concerning them, and anyone contemplating work involving such measurements would be well advised to study the details set out in this report regarding the difficulties that arose and the modifications that were introduced to overcome them and improve the techniques. Rod scotometry is dealt with in detail, in addition to the more usual dark-adaptation measurements.

Good liver reserves of vitamin A are offered as the explanation of the delayed onset of any detectable sign of depletion. Reported values for the general population of Great Britain suggested that it was not unreasonable to expect a total reserve of about 500,000 I.U. If the normal rate of utilization is approximately 1,300 I.U. daily, this reserve would last about 400 days. Support for a figure of this order comes from the fact that none of the volunteers was markedly depleted in less than 400 days, and the smallest therapeutic dose tested (1,300 I.U. of vitamin A daily) proved adequate to restore the capacity for dark adaptation to normal.

It was noted that abnormal values for dark adaptation did not occur unless the plasma-level of vitamin A had fallen below 50 I.U. per 100 ml. Plasma-levels among the general population are reported to be 100–120 I.U. per 100 ml., "but it is not known whether values as high as these are necessary for optimum health". In the test subjects, dark-adaptation values returned to normal when the plasma value returned to about 50, and showed no further improvement when the dose of vitamin A was increased, although plasma-levels did not return to 100 or above until after a period of unrestricted diet coupled with very large doses of vitamin A. The smallest prophylactic dose tested was 2,600 I.U. daily. This maintained normal dark adaptation and

* Vitamin A Requirement of Human Adults; an Experimental Study of Vitamin A Deprivation in Man. A Report of the Vitamin A Sub-committee of the Accessory Food Factors Committee. Medical Research Council Special Report Series, No. 264. Pp. 145. (London: H.M. Stationery Office, 1949.) 3s. net.

a steady plasma-level; probably a smaller dose would have sufficed.

When carotene was used instead of the preformed vitamin, it was necessary to distinguish carefully between the value of the dose as given and its 'effective value'. The latter was taken as the difference between the amount given and the amount excreted, but it is pointed out that it is not known if this represents the amount actually absorbed; there may be some destruction in the gut. Even with pure carotene in oil, approximately 25 per cent of the dose was excreted; when green leaves or carrots were given, the proportion rose much higher, averaging 75 per cent with sliced or *purée* tinned carrots. When due allowance had been made for these differing levels of availability, it appeared that the minimum protective dose lay between 1,250 and 1,900 I.U., and an effective dose of 1,500 I.U. was adopted as the probable daily requirement in terms of β-carotene.

The fact that the volunteers had to be kept for a year or more on a restricted vitamin-A-free diet before their reserves were sufficiently depleted to make them suitable subjects for therapeutic tests reduced the numbers available and made repetition of the experiments impracticable. In drawing conclusions from the results and, still more, in making recommendations based on them, it is necessary to make some allowance for individual variability among normal adults. The authors point out that "it is difficult to decide whether doubling the [minimum protective] dose would confer the maximum improvement in health or whether the dose should be increased fourfold, eightfold or even more". They have taken their courage in both hands, however, and been content with doubling it, recommending "a round figure of 2,500 I.U. vitamin A daily for a normal human adult". They back their decision with the observation that "the very adequate liver reserves of the subjects of the experiment cannot have been built up in the past on daily intakes much larger than 2,500 I.U. vitamin A or an equivalent mixture of carotene and vitamin A.". They have chosen 3,000 I.U. as the desirable level when the source is carotene, but stress the fact that, in order to ensure this, the diet may well have to supply about 12,000 I.U.

In the War Memorandum of the Medical Research Council on the nutritive value of war-time foods[3], it was suggested that "in calculating the vitamin A potency of *a mixed diet*, the total carotene value should be divided by 3 and added to the value for preformed vitamin A. . . . This correction should not be applied to *individual foods* for which it is to be expected that different correction factors will be found necessary."

The present report recommends dividing by 4 when the source is carrot and by 2·5 when the source is cabbage or spinach, and suggests that, in the absence of data for the availability of carotene in other foods, other root vegetables should be classed with carrots, and other green leaves with cabbage and spinach. The original recommendation (division by 3) has been fairly widely used and has led to much confusion in the assessment of the vitamin A adequacy of different dietaries, for the resultant 'vitamin A potency' has been compared with recommended allowances where no such correction has been applied, and 'deficiencies' reported when, in fact, the deficiency was only in the interpretation.

Dietary survey material is very apt to give rise to these miscegenations of fact and theory—the use of man-value coefficients was another potent source of much misunderstanding. Reports of food consumption studies often omit the only factual data that were collected, that is to say, the amounts of the various *foods* that were eaten. Instead, we are given calculated nutrient values which rarely make any allowance for the effect of the preparation and cooking methods employed, even when they introduce some minor 'correction factor' for availability.

There can be little doubt that the physiological value of a dietary is determined by a large number of different factors, not the least of which is the 'dietary pattern' or way in which the foods are mixed and the intake spaced. We are only beginning to learn about these things, and most of the earlier studies will need to be re-assessed in the light of more recent discoveries. Unfortunately, it is often impossible to do this because of the way in which the data have been presented.

Meantime, in regard to vitamin A, it might be suggested that estimates of *requirements* should always be given in terms of vitamin A *per se*, and that reports of *food consumption* should state the quantities of vitamin A and carotene separately, the estimation of the resultant vitamin A potency being given as an additional figure, together with a description of how it was obtained. Further, is it not time now to drop the 'I.U.' and use 'mgm.' or 'μgm.' instead, as with the other vitamins?

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NEWS and VIEWS

Education in the University of Leeds

MR. ROGER NOEL ARMFELT has been appointed professor of education and head of the Department of Education from a date early in the session 1949–50, in succession to Prof. W. R. Niblett, who becomes whole-time director of the University of Leeds Institute of Education. Prof. Niblett was appointed professor of education and head of the Department of Education in 1947, and since September 1948 he has also been director of the Institute of Education. His tenure of both the headship of the University Department and the directorship of the Institute was a temporary measure, and Mr. Armfelt's appointment is a realization of plans made when the Institute was established in 1948. Mr. Armfelt was educated at Cranleigh and at King's College, Cambridge. After a period as assistant master at Dulwich College, he was successively an inspector with the Kent Education Committee, assistant secretary with the Buckinghamshire Authority and secretary to the Devon Education Committee. In 1941 he was appointed an assistant controller in the Home Division of the B.B.C., and in 1945 transferred to the secretaryship of the Schools Broadcasting Council. His publications include "County Affairs", "Village Affairs", "Shapton Affairs", and most recently, "Education—New Hopes and Old Habits".

Finnish Geodetic Institute : Prof. I. Bonsdorff

To commemorate the seventieth birthday of Prof. Ilmari Bonsdorff, for more than thirty years director of the Finnish Geodetic Institute, Helsinki, No. 36 of the *Veröffentlichungen* (1949) of the Institute is dedicated to him. It contains twenty-six articles by Finnish and foreign geophysicists written in tribute to Prof. Bonsdorff. He began his long scientific career as an astronomer at the observatory of Poulkovo, near Leningrad, where he worked on astrometry and geodesy. In 1918 he returned to his home country to take up the directorship of the Geodetic Institute at Helsinki, where he conducted and inspired a long series of valuable researches. He took also a prominent part in international geodetic co-operation, both through the International Union of Geodesy and Geophysics, and through the Baltic Geodetic Commission, which was established on his initiative and was served by him as secretary-general throughout the whole period of its existence. Among the non-Finnish contributors to this collection of articles may be noted E. C. Bullard, B. Gutenberg, K. D. P. Rosen, P. Tardi and F. A. Vening Meinesz.

Prof. W. A. Heiskanen

Prof. Bonsdorff has now resigned from the directorship of the Finnish Geodetic Institute, and has been succeeded by Prof. W. A. Heiskanen. Prof. Heiskanen was born in 1895 in Kangaslampi, Finland. He was senior geodesist in the Finnish Geodetic Institute during 1921–28, lecturer in geodesy in the University of Helsinki from 1926, professor of geodesy in the Finland Institute of Technology during 1928–49, chief of the Geodetic Section of the Finland Institute of Technology during 1935–49, and director of the International Isostatic Institute from 1936. He was also a member of the Finnish Parliament during 1933–36. He was chairman of the Finnish Geographical Society during 1941–42, chairman of the Astronomical Society Ursa for about fifteen years, member of the Finnish Academy of Sciences from 1928, member of the Norwegian Academy of Sciences from 1947, and honorary member of the Geographical Society of Netherlands from 1938. The most important of Prof. Heiskanen's scientific works concern isostasy, the figure of the earth, and the distribution of gravity on the earth's surface. Most of these works are published in the series of the Finnish Geodetic Institute, the Baltic Geodetic Commission, the International Association of Geodesy, and the Isostatic Institute.

Research Council of Israel

The former Board of Scientific and Industrial Research of the Government of Palestine has now been succeeded by the Research Council of Israel. The Council is composed of twelve men of science and representatives of the research institutions in Israel, and the work includes the co-ordination of research carried out in Israel, co-operation with similar bodies of other countries, and the financing of research projects of specific local interest. The work of the Council is conducted by five committees, dealing with research in fundamental science, industry, building, food and agriculture. Instrument and information divisions have already been established. Prof. S. Sambursky, of the Physics Department, Hebrew University, Jerusalem, has been appointed director and executive secretary of the Council. The Council expects to issue publications on the various subjects being studied, and has already published a report, entitled "Problems of Vole Populations in the Middle East", by Prof. F. Bodenheimer.

Israel Institute of Public Opinion Research

Dr. Louis Guttman, associate professor of sociology at Cornell University, has completed a two-year research programme in Israel as a field Fellow of the Social Science Research Council and has been largely instrumental in the founding of the recently formed Israel Institute of Public Opinion Research. He has been invited to remain in Israel for another year to serve as chief consultant and direct the activities of the Institute, and associated with him will be Dr. Uriel G. Foa, formerly of the Hebrew University, as executive director. Experimental attitude-studies conducted before, during and after the siege of Jerusalem have shown that American techniques and methods of research are equally appropriate for the diverse populations of Israel. In particular, experiments have been successful with scale and quasi-scale theory, and the intensity component for obtaining unbiased results. A new discovery is that of the third component of scalable attitudes (beyond the intensity component) that oscillates twice with respect to the attitude. Other new discoveries relating to experimental methods are in the process of being consolidated. The Institute is at present under Government auspices, and is engaged in a study of the adjustment of new immigrants to Israel. But, in addition to its continuing surveys of public opinion, the Institute will conduct research for civic and private organisations and will undertake special projects in the fields of market research, consumers' problems, social and civic problems, industrial psychology, and in other areas of a social psychological nature. Future plans include publication of a periodical bulletin in English on the activities and results of the Institute. Communications should be addressed to the Israel Institute of Public Opinion Research, P.O.B. 49, Jaffa, Israel.

Electrical Supply Research Council

Sir Harold Hartley, chairman of the British National Committee and International Executive Council of the World Power Conference, has accepted the chairmanship of the Electricity Supply Research Council set up by the British Electricity Authority. Other members who have accepted invitations to serve are : Sir Edward Appleton, Prof. F. E. Simon, Sir David Brunt, Prof. H. W. Melville, Sir Geoffrey Taylor, Mr. V. A. Pask and Mr. C. W. Marshall. Additional nominations will be made to represent the Electricity Boards. The terms of reference of the Council are : (*a*) to advise the central authority and area boards on specific problems relating to electricity supply ; (*b*) to keep under review matters affecting the supply of electricity and to advise the central authority and area boards on programmes and planning of research carried out over the whole field ; and (*c*) to make recommendations to the central authority on research which the Council considers it desirable to initiate.

Cosmic Ray Expedition

This month (August 1949) a party of American men of science, sponsored by the National Geographic Society and by the Bartol Research Foundation, will

visit the Canadian settlement Churchill on Hudson Bay, to investigate the cosmic-ray intensity at a height of twenty miles. A fourfold coincidence arrangement of Geiger counters carried aloft on free balloons will be used, and the observations, together with data for the atmospheric pressure, and the temperature within the apparatus, will be transmitted by radio and recorded on moving tape on the ground. Previous height measurements of cosmic rays up to 30,000 ft. were made with specially equipped B-29 aircraft. Churchill is chosen as the venue of the expedition because of its high geomagnetic latitude (69°). It is hoped to determine whether at 100,000 ft. height the cosmic-ray intensity continues to increase with geomagnetic latitude; if not, one interpretation would be that the cut-off is caused by the action of a solar magnetic field. Canadian meteorologists stationed at Churchill will take part in the work. It may be hoped that it has been possible to arrange to use these flights for the determination of the winds at 100,000 ft., on which our information is still very scanty.

Prevention of Corrosion by Vapour-phase Inhibitors

ADVANCES within recent years in corrosion-preventive packaging have included the use of 'vapour-phase inhibitors'. These are organic compounds, solid at ordinary temperatures, the vapour of which, by surrounding the metal article within a closed container, produces on the surface an invisible protective film. Corrosion of the article is thereby prevented, even in the presence of condensed moisture, actual contact with the solid inhibitor being unnecessary. Much work in this field has been carried out by the oil industry, and a product stated to have a high degree of efficiency has recently been announced by Shell Chemicals, Ltd., 112 Strand, London, W.C.2. The substance, 'Shell V.P.I. 260', is described as a white crystalline compound, odourless and non-toxic; according to the patent specification it is the nitrite salt of an organic nitrogen base. Applicable in powder form or in solution, the most convenient method is stated to be by use of coated wrapping materials. The article is enclosed in the impregnated wrap, and the protective vapour permeates to every recess. Hermetic sealing is not necessary, but longer life is afforded by a further wrap in a waxed or laminated paper; impregnated heavy cloths can be used to protect equipment or materials in process. Steel appears to be particularly amenable to rust-prevention by traces of the inhibitor even when moisture condenses. Other metals protected by 'V.P.I.260' are stated to be aluminium, duralumin, cast-iron and chromium plate.

Forest Research Institute and Colleges, Dehra Dun

To those who have known of and followed the history of the Forest Research Institute at Dehra Dun since its first inception in India by Lord Curzon and Sir S. Eardley Wilmot in 1906, it may appear curious that the president of the Institute and Colleges should have considered it necessary to issue a pamphlet on its scope and functions. The notable part the Institute has played in forest research and the remarkable results achieved during the two world wars in making India independent of many types of imports have been noted in *Nature* from time to time. The British forest officers who started and brought the Institute to its present fine position in the world of forest research have left a great legacy in the hands of their Indian successors. The present publication is doubtless intended chiefly for the new India and Pakistan, and for that purpose it may be hoped that it will be widely read. Those interested in forestry research in different parts of the world will follow with keen interest the future progress made by the Dehra Dun Institute under its president, Mr. C. R. Ranganathan, to whom all its well-wishers will wish every success.

Journal of Research and Development: British Cast Iron Research Association

FROM August onwards the *Journal of Research and Development* issued by the British Cast Iron Research Association will cease to be a confidential publication and will be generally available to non-members of the Association on subscription terms. This decision has been based chiefly on the large increase in membership of the Association; it is now felt that it is neither practicable nor desirable to maintain the confidential status of a journal which is so widely circulated. The *Journal* contains reports of complete investigations conducted by the research and development staffs of the Association, together with papers presented at Association conferences, and a wide variety of subjects is dealt with. The *Journal* is published in alternate months, six issues a year, and the annual subscription is £2 or eight dollars, post paid. The first number of Volume 3 will appear in August; subscriptions can be sent through booksellers or direct to the British Cast Iron Research Association, Alvechurch, Birmingham.

Aeolotrophy and Seismology

THE mathematical problem of the seismological implications of æolotropy in continental structure has been discussed by Robert Stoneley (*Mon. Not. Roy. Astro. Soc.*, Geophysical Supplement, **5**, No. 8, 343; 1949). He finds that for near earthquakes, erroneous values of the focal depth and thickness of layers might be found from the observations if the continental material had been thought to be isotropic. Further, for a transversely isotropic continent, *SH* waves would travel with a different velocity from that of *SV*, and the law of variation of velocity with direction would be different. With body waves, the sharp distinction into compressional and distortional waves would not hold, and an explosion would generate an *S* wave as well as a *P* wave; an apparent difference in the instant of generation of *P* and *S* might arise. Stoneley has also proved that waves of the Rayleigh type can be propagated over the surface of a transversely isotropic body in which the axis of circular symmetry is normal to the free surface, supposed plane; in such waves the diminution of amplitude with depth is shown to be different from that in an isotropic body, so that the amplitudes of the surface waves generated by a source at a given depth will be different from that which they would be in an isotropic medium. Love waves can be propagated as in isotropic media. Byerly noted a possible double refraction effect on the crust of the earth for waves from the earthquake of July 6, 1934 (*Bull. Seism. Soc. Amer.*, **28**, 12; 1938). Miss I. Lehmann may also have noted a similar effect (*Pub. Bur. Cent. Séism. Int.*, A, No. 12, 109; 1935).

Bibliography of Seismology

VOL. 14, No. 3, of the Bibliography of Seismology from the Dominion Observatory, Ottawa, has been compiled by W. G. Milne (pp. 51–70. Ottawa: King's

Printer; 1948. 25 cents). It contains 124 items (6734–6857) concerning pure and applied seismology, together with lists of patents taken out in connexion with the latter. The survey is world wide. Included are important items on recent research in large-scale geophysical exploration using artificial earthquakes caused by the detonation of surplus explosives. Work by Bullard and Charlier on explosions in Germany, Gamburtsev in U.S.S.R. and J. Tuzo Wilson and others in Canada all bear on this. Papers on microseisms by Deacon, Barber and Ursell of the Admiralty Research Laboratory, Macelwane and others in America, Bernard in France, Amorós and others in Spain, Hodgson in Canada, and Jones in the Pacific area, are listed. This subject, which was at one time only an annoyance to seismologists since the microseisms confused their records of earthquakes, now has important practical meteorological and oceanographic applications.

First International Congress of Biochemistry

THE First International Congress of Biochemistry, initiated by the Biochemical Society, will be held in Cambridge during August 19–25 under the presidency of Prof. A. C. Chibnall. The holding of this Congress marks a definite stage in the development of biochemistry as the branch of science covering that ill-defined territory between chemistry and the many branches of biology. The need for an international congress on this subject has been evident for some time; indeed, eight congresses for French-speaking biochemists have already been organised since 1927 by the Société de Chimie Biologique. The list of distinguished chemists and biochemists who have consented to be honorary vice-presidents is truly international: Prof. J. P. Collip (Canada), Prof. N. E. Cruz-Coke (Chile), Prof. M. Florkin (Belgium), Prof. A. J. Kluyver (Netherlands), Prof. K. Linderstrøm-Lang (Denmark), Academician J. O. Parnas (U.S.S.R.), Prof. J. Roche (France) and Dr. D. D. van Slyke (United States).

The Congress lecturers will be Prof. C. F. Cori (United States), Prof. M. Florkin (Belgium) and Sir Robert Robinson (Great Britain). The Congress will be officially opened on August 19 by the president, and this ceremony will be followed in the evening by a reception by the Government, when the host will be Viscount Addison. The Congress will be divided into various sections which are numbered as follows: (1) animal nutrition and general metabolism; (2) microbiological chemistry; (3) enzymes and tissue metabolism; (4) proteins; (5) clinical biochemistry; (6) structure and synthesis of biologically important substances; (7) cytochemistry; (8) biological pigments, oxygen carriers and oxidizing catalysts; (9) hormones and steroids; (10) chemotherapy and immunochemistry; (11) plant biochemistry; (12) industrial fermentation. On August 20, to mark the occasion of the Congress, the University of Cambridge will confer the degree of honorary D.Sc. on six distinguished delegates. Various social functions, visits, etc., are being arranged during the period of the Congress. Officers of the Congress include: *Treasurer*, Dr. L. H. Lampitt; *Joint Honorary Secretaries*, Dr. E. Baldwin and Prof. F. Dickens; *Hon. Organiser*, Francis J. Griffin; *Chairman of the Congress Committee*, Sir Charles Harington; *Chairman of the Executive Committee*, Prof. E. C. Dodds. Further information may be obtained from the Honorary Organiser, First International Congress of Biochemistry, 56 Victoria Street, London, S.W.1.

Oil Shale and Cannel Coal Conference of the Institute of Petroleum

AFTER the first Oil Shale and Cannel Coal Conference in June 1938, it was resolved that the Institute of Petroleum should consider the question of holding a similar conference within the next ten years. This has not been possible, owing to the War; but 1950 is the centenary year of the James Young patent which led to the foundation of the Scottish shale oil industry, and it is therefore proposed to convene the second Conference on Oil Shale and Cannel Coal to meet in Glasgow during the week commencing July 3, 1950. At the same time the Young centenary will be celebrated by a Young Memorial Lecture. The technical sessions of the Conference will be in three sections, as follows: *A*—geology and mining; *B*—retorting, refining and uses of by-products; *C*—economics and statistics. An all-day visit to a shale mine and shale-oil refinery will be a feature of the Conference. Further information can be obtained from the Secretary of the Institute of Petroleum, 26 Portland Place, London, W.1.

Beit Memorial Junior Fellowships for Medical Research

IT has recently been announced that Beit Memorial junior fellowships for medical research (normal value £600 per annum) have been awarded as follows: D. V. Bates (Cambridge), to carry out research on respiratory functions, at the Dunn Laboratory, St. Bartholomew's Hospital, London; D. B. Carlisle (Oxford), to study the mechanism of the production of the anterior pituitary hormones, at the Department of Zoology and Comparative Anatomy, University of Oxford; Dr. B. Cinader (London), to investigate the formation of multiple antibodies to a single antigen and to examine their properties, at the Lister Institute of Preventive Medicine, London; Dr. J. T. Davies (London), to investigate the nature of the excitation of living cells by examining the closely similar case of built-up films of materials which recent work suggests to be responsible for the permeability of cell walls, at the Royal Institution; D. T. Elmore (London), to examine the hydrolysates of nucleic acids, at the University Chemical Laboratory, Cambridge; Dr. A. S. Jones (Birmingham), to study the immunochemistry of bacterial nucleic acid complexes, at the A. E. Hills Laboratories, Chemistry Department, University of Birmingham; June Lascelles (Sydney), to study the metabolic function of folic acid and para-aminobenzoic acid, at the Department of Biochemistry, University of Oxford; E. Reid (Aberdeen), to study the pituitary growth hormone in relation to metabolic processes, at the School of Biochemistry, University of Cambridge; B. D. Wyke (Sydney), to carry out quantitative studies on the electrical activity of the brain in patients with various types of central nervous system disorders of both organic and functional type, at the Department of Surgery, University of Oxford and Radcliffe Infirmary, Oxford.

DR. EDWIN HUBBLE, of Mount Wilson Observatory, and Dr. B. Lindblad, director of the Stockholm Observatory, have been elected *correspondants* for the Section of Astronomy, and M. Léon Moret, professor of geology in the University of Grenoble, *correspondant* for the Section of Mineralogy, of the Paris Academy of Sciences.

SPIRALLING IN SPORANGIOPHORES OF *PHYCOMYCES* FOLLOWING A TEMPORARY CESSATION OF GROWTH

By Dr. R. D. PRESTON and MAVIS MIDDLEBROOK
University of Leeds

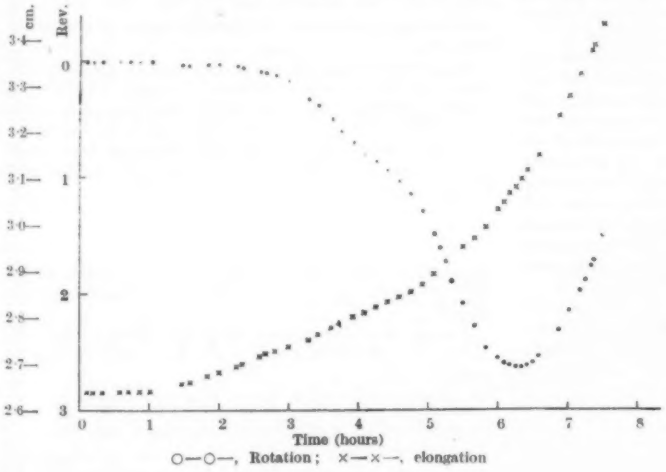
AN attempt was made some time ago[1] to relate spiral growth in sporangiophores of *Phycomyces* to the physical properties of the wall, and the successful semi-quantitative test of the relation proposed against the data of Castle[2], as well as the more recent extension to the case of spiral grain in conifers[3], makes it reasonable to assume that, oversimplified though the relation undoubtedly is, it does express spiral growth in terms of the appropriate parameters. Assuming for simplicity that the 'fibrils' in the wall of the growth-zone are circular in section (though this is not an essential part of the theory) it appears that the rotation of the tip of the sporangiophore, $\Delta\varphi$, associated with a length increase of ΔL is given by the relation

$$\frac{\Delta\varphi}{\Delta L} = \frac{\cos\alpha \sin\alpha \left(1 - \frac{2n}{q}\right)}{a\left(\cos^2\alpha + \frac{2n}{q}\sin^2\alpha\right)}, \qquad (1)$$

where n is the torsional rigidity, q the Young's modulus of the fibrils, α the angle between the fibril direction in the wall and the longitudinal plane, and a the diameter of the sporangiophore.

During the past eighteen months we have been engaged in making observations suggested by relations of the type (1) above, in order to test further the validity of the underlying ideas, and have succeeded in showing that α is of the correct order of magnitude and that the relation between $\Delta\varphi/\Delta L$ and a is of the kind predicted. These points will be reported upon elsewhere. The purpose of this note is to present a series of observations which seem of even greater significance. Normally a sporangiophore rotates left-handed (that is, viewed from above, the tip rotates in a clockwise direction). The resumed growth after the expansion of the sporangium, however, is associated with a *right hand* spiralling which afterwards slows down and changes to left-handed, the whole process lasting about 1½–2½ hours. Such a reversal of spiralling can be explained in terms of relation (1) on the assumption that, since the wall of the growth zone is free of growth stresses during the expansion of the sporangium, its value of n becomes unusually high or of q unusually low, or both, so that $(1 - 2n/q)$ becomes negative. Resumption of elongation would then be associated with right-hand spiralling which, as n decreased and q increased to the normal value during growth, would slow down and reverse to left-hand spiralling. It follows, therefore, that, if this explanation is correct, cessation of growth at *any* time would produce right-hand spiralling on its resumption, and this is the point we wish to discuss here.

Sporangiophores of *Phycomyces nitens* + were grown to stage IV*b* on malt agar under standard conditions. This is the final stage during which the sporangiophore continues to rotate uniformly left-handed for several hours until the dehiscence of the sporangium. It is possible to stop growth at any time by any one of a variety of agents. Irradiation with ultra-violet, for example, is very effective; but it is difficult to ensure later resumption of normal growth, presumably on account of the serious injury involved. For the moment, therefore, we have preferred to use an alternative method, the complete immersion of the sporangiophore in water. This stops growth completely for a very considerable period, with no signs of damage after the water has been removed. In practice, however, the use of water alone has proved impossible since surface tension effects invariably cause the long, erect, delicate sporangiophores to be pulled flat on the substrate. We have therefore reduced the surface tension by the addition of dodecyl trimethyl ammonium bromide to the extent of 0·002 per cent. The method is to immerse the sporangiophore in the solution for half an hour or so and then to pipette off the solution, supporting the sporangiophore meanwhile with a cover-glass held vertically against it. The rate of elongation is then observed by means of a cathetometer microscope, and of rotation by means of an Ultrapak microscope held vertically over the sporangium and carrying a pointer eyepiece with a circular scale, graduated in degrees. Rotation is followed by noting the angular position of *Lycopodium* spores dusted on the sporangium, and the result of one typical series of observations is presented in Fig. 1. As the sporangium begins to elongate, rotation begins simultaneously and is then right-handed. This rotation continues for about five hours, after which it becomes progressively slower and ultimately



○—○—, Rotation; ×—×—, elongation

changes to left-handed. The final rates of elongation and rotation appear quite normal for sporangiophores of stage IV*b*.

In a qualitative sense, therefore, growth proceeds much as predictable from relation (1), and this may be taken as a striking confirmation of its general validity. The low value of $\Delta\varphi/\Delta L$ during the first two hours or so of elongation would seem to indicate merely that the relation is too simple to express precisely the phenomena involved, at least during the early period. It is not proposed here to examine at all the effects of submersion which might inhibit growth, nor is it possible at the moment to discuss either the changes in the wall during immersion or the possibility that the detergent itself might have some effect. These are points for future research. It is now quite clear, however, that a period of rest, whether natural or enforced, induces such changes in the wall that subsequent growth is in a sense abnormal. This might be of some importance in growth studies generally.

[1] Preston, R. D., *Biochim. et Biophys. Acta*, **2**, 155 (1948).
[2] See, for example, Castle, E. S., *Amer. J. Bot.*, **29**, 654 (1942).
[3] Preston, R. D., *Forestry* (in the press, 1949).

CALCULATION OF SELF-ENERGY OF PARTICLES

Meson with Spin Zero

THE wave equation usually employed to describe the interaction between two fields is non-relativistic in form, since in it the time co-ordinate is singled out. To remedy this defect, Tomonaga[1] has proposed a covariant formulation of quantum electrodynamics with the wave equation

$$\left(H_C(P) + \frac{\hbar}{i}\frac{\delta}{\delta C_P}\right)\psi[C] = 0. \qquad (1)$$

C is a space-like surface through the point P in four-dimensional space, which defines the time t as a function of the spatial co-ordinates, and $\psi[C]$ is a functional of this surface. $H_C(P)$ is the Hamiltonian density for the interaction of the two fields. Tomonaga and his co-workers have studied the new wave equation for the interaction of the electromagnetic field with electrons[2], and with scalar, pseudoscalar[3] and vector[4] mesons.

This covariant formalism has been applied by Schwinger to problems arising from the interaction of electrons with the electromagnetic field[5]. He found that the self-energy and the self-charge of the electron diverge logarithmically. However, they are expressed as invariant integrals over an invariant variable, and therefore could both be made finite by a relativistically invariant cutting-off process. A notable success of the Schwinger theory is that it accounts for the Lamb–Retherford shift of the energy-levels of an atom and for the anomalous magnetic moment of the electron.

Similar calculations for the meson with spin zero have been carried out, and the following is a report of some results derived for the self-energy problem. The relevant Hamiltonian is[3]

$$H_C(P) = \frac{1}{4\pi}\left[\frac{ie}{\hbar c}A_a\left(\varphi^*\frac{\partial\varphi}{\partial x_a} - \frac{\partial\varphi^*}{\partial x_a}\varphi\right) - \left(\frac{ie}{\hbar c}\right)^2\varphi^*\varphi\{A_a^2 + (N_a A_a)^2\}\right],$$

where N_a denotes the unit vector normal to the surface C at P and pointing towards the future. The invariant term $\varphi^*\varphi\{A_a^2 + (N_a A_a)^2\}$ has been introduced into $H_C(P)$ by Kanesawa and Tomonaga to make the wave equation (1) integrable. We now write

$$H_C(P) = H_1(x) + H_2(x),$$

where $H_1(x)$ is linear and $H_2(x)$ is quadratic in the e's or A's and x denotes the co-ordinates of P. The self-energy is described theoretically by the emission and reabsorption of a virtual photon by the meson and therefore cannot, in a first approximation, be due to H_1. Limiting our considerations to terms of the second order in e, we transform away H_1 and obtain the new wave equation

$$i\hbar\frac{\partial\psi}{\partial C_P} = \left(H_2(x) + \frac{i}{4\hbar c}\left\{\int_{-\infty}^{C} + \int_{+\infty}^{C}\right\}[H_1(x'), H_1(x)]\,dx'\right)\psi.$$

The new Hamiltonian must be evaluated for the self-energy problem. It is readily found that $H_2(x)$ yields the contribution

$$\frac{3}{2\times 137}I(0)\,\varphi^*(x)\,\varphi(x),$$

where

$$I(z) = \frac{i}{4\pi^2}\int_{-\infty}^{+\infty}\exp(-i\alpha z_\mu^2)\,\frac{\alpha}{|\alpha|}\,d\alpha. \qquad (2)$$

$I(z)$ is really the relativistic Δ_1-function, for which Schwinger has given the above representation by means of an invariant variable α which has the dimensions of a reciprocal mass squared. If $z_\mu^2 \neq 0$, $I(z)$ is the principal value of $1/2\pi^2 z_\mu^2$. Defining $I(0)$ as the limit of $1/2\pi^2 z_\mu^2$ as z_μ^2 tends to zero, we obtain the quadratic divergence which has already been derived by elementary methods[6]. If, on the other hand, we put z_μ^2 equal to zero before allowing the limits of integration to go to infinity, we deduce that

$$I(0) = \frac{i}{4\pi^2}\lim_{R\to\infty}\int_{-R}^{+R}\frac{\alpha}{|\alpha|}\,d\alpha = 0. \qquad (3)$$

So the result is ambiguous. As Wentzel[7] has pointed out in his investigations on the self-energy of the photon, quantum electrodynamics is not unambiguous when it deals with divergent results. In view of the ambiguity, we define $I(0)$ by (3) and obtain a vanishing contribution to the self-energy of the meson from $H_2(x)$.

The evaluation of the contribution to the self-energy from the second term of the new Hamiltonian is more tedious. One must pick out the part of the commutator $[H_1(x'), H_1(x)]$ which refers to one meson and no real photon. On expanding φ into plane waves, one finds that the contribution to the self-energy now obtained is

$$-\frac{1+3K}{16\pi^2}\,\frac{1}{137}\,\varkappa^2\varphi^*(x)\varphi(x),$$

where $K = \log\eta$ and η is an invariant which should tend to zero. So this contribution diverges logarithmically.

To see the significance of these results, we write down the Hamiltonian for the free field of mesons without spin:

$$\frac{1}{4\pi}\left(\frac{\partial\varphi^*}{\partial x_1}\frac{\partial\varphi}{\partial x_1} + \frac{\partial\varphi^*}{\partial x_2}\frac{\partial\varphi}{\partial x_2} + \frac{\partial\varphi^*}{\partial x_3}\frac{\partial\varphi}{\partial x_3} - \frac{\partial\varphi^*}{\partial x_4}\frac{\partial\varphi}{\partial x_4} + \varkappa^2\varphi^*\varphi\right),$$

where $\varkappa = \frac{mc}{\hbar}$, m being the mass of the meson.

The diverging contribution affects only the last term of the Hamiltonian, so the self-energy leads to a mass correction, m^2 being replaced by

$$m^2\left\{1 - \frac{3K+1}{4 \times 137\pi}\right\}.$$

By invariantly cutting off a variable with the dimensions of a mass squared, we can make η non-vanishing and so re-normalize the mass. In this way the self-energy can be eliminated.

I wish to thank Prof. W. Heitler, Dublin Institute for Advanced Studies, for suggesting these investigations, and for helpful discussions.

J. McConnell

St. Patrick's College,
Maynooth.
Feb. 25.

[1] *Prog. Theor. Phys.*, **1**, 40 (1946).
[2] Koba, Z., Tati, T., and Tomonaga, S., *Prog. Theor. Phys.*, **2**, 101, 198 (1947).
[3] Kanesawa, S., and Tomonaga, S., *Prog. Theor. Phys.*, **3**, 1 (1948).
[4] Kanesawa, S., and Tomonaga, S., *Prog. Theor. Phys.*, **3**, 101 (1948).
[5] *Phys. Rev.*, **74**, 1439 (1948); **75**, 651 (1949).
[6] Cf. Gupta, S., *Proc. Nat. Inst. Sci., India*, **9**, 173 (1943).
[7] *Phys. Rev.*, **74**, 1070 (1948).

Particles with Spin One

Kanesawa and Tomonaga[1] have extended the many-time formalism to the interaction of vector and scalar (or pseudoscalar) particles with the electromagnetic field. In a previous note[2] one of us (McC.) has already used this formalism to calculate the electromagnetic self-energy of particles with spin zero and found that, so far as the well-known quadratic divergence is concerned[3], the result is ambiguous and that this 'quadratic divergence' may also be given the value zero (or any other value). We have now also calculated the self-energy of a particle with spin one, up to terms in e^2.

Let φ_μ be the vector-wave field of the particle and

$$\chi_{\mu\nu} = \frac{\partial \varphi_\nu}{\partial x_\mu} - \frac{\partial}{\partial x_\rho}.$$

For a free particle the canonical momentum P_i conjugate to φ_i (space components) is given by $4\pi P_i = -i\chi_{i4}^*$, and φ_4 can (and in the Hamiltonian must) be expressed by P_i, namely, $m_0^2\,\varphi_4 = 4\pi i \frac{\partial P_i^*}{\partial x_i}$, where m_0 is the mass of the particle (units $\hbar = c = 1$). The Hamiltonian density of the free particle is then

$$4\pi H_0 = \tfrac{1}{2}\chi_{ik}^*\chi_{ik} + 16\pi^2 P_i^* P_i + m_0^2\varphi_i^*\varphi_i + \frac{16\pi^2}{m_0^2}\frac{\partial P_i^*}{\partial x_i}\frac{\partial P_k}{\partial x_k}. \quad (1)$$

The self-energy is found to consist of two contributions, (i) arising from terms linear in A_μ of the interaction Hamiltonian, (ii) arising from terms quadratic in A_μ. The first contribution is found to be

$$H_1 = -\frac{7+18K}{9\cdot 4\pi^2\,137}\, m_0^2\,\varphi_\mu^*\,\varphi_\mu, \quad (2)$$

where K is logarithmically infinite: $K = \log \eta$. $\eta \to 0$, and η is an invariant. At first it looks as if (2), when added to the Hamiltonian (1), has not the property of merely modifying the mass, because $4\pi H_0$ is $m_0^2(\varphi_i^*\varphi_i - \varphi_4^*\varphi_4)$ so far as it depends on m_0. However, m_0 also enters in the connexion between φ_4 and P_i, and if we express (2) in terms of P_i (as we must do) we have:

$$\varphi_\mu^*\varphi_\mu = \varphi_i^*\varphi_i - \frac{16\pi^2}{m_0^4}\frac{\partial P_i^*}{\partial x_i}\frac{\partial P_k}{\partial x_k}.$$

If we now add (2) to H_0, and assume that K is 'in reality' finite and small, it appears that H_1 has the effect of changing the mass $m_0^2 \to m^2 = m_0^2 + \delta m_0^2$. The contribution H_1 is unambiguous. It has much the same structure as was found by Schwinger[4] for the self-energy of particles with spin half.

The second contribution is

$$H_2 = \frac{1}{2\times 137} I(0)\left(2\varphi_\lambda^*\varphi_\lambda + 2N_\mu N_\rho\,\varphi_\mu^*\varphi_\rho + \frac{1}{m_0^2}N_\mu N_\rho\,\chi_{\lambda\mu}^*\chi_{\lambda\rho}\right), \quad (3)$$

where N_μ is the 4-vector perpendicular to the time surfaces and, if the latter is plane, has the components $N_\mu = 0, 0, 0, i$. Then H_2 becomes

$$H_2 = \frac{1}{2\times 137} I(0)\left(2\varphi_i^*\varphi_i - \frac{1}{m_0^2}\chi_{i4}^*\chi_{i4}\right),$$

I is defined by:

$$I(z) = \frac{1}{2\pi^2}\frac{\mathbf{P}}{z_\mu^2}.$$

(**P** denotes the principal value.)

We first note that $I(0)$ is ambiguous, in the same way as was found for particles with spin zero[2]. It can be defined as quadratically infinite or zero. Secondly—and this is peculiar for particles with spin 1—H_2 has not the correct transformation properties of a mass contribution. It appears, therefore, necessary that H_2 should be made to vanish unambiguously. Quantum electrodynamics, as it stands, is unable to do this, and a departure from the Heisenberg–Pauli formalism is required.

A preliminary step in this direction has recently been taken by Pauli and Villars through their process of regularization[5]. This is a generalization of a procedure suggested by Feynmann[6] and by Stückelberg and Rivier[7]. The procedure, which is described in detail in ref. 5, consists of the introduction of auxiliary masses M_i, and replacing expressions like $I(z)$ by a sum with each term depending on one M_i, such that: (i) each term vanishes when $M_i \to \infty$, (ii) the singularity of (5) on the light cone for $z_\mu^2 = 0$ disappears, when M_i is finite. If we then evaluate $I(0)$ first, before letting $M_i \to \infty$ (and afterwards put $M_i \to \infty$), $I(0)$ becomes zero unambiguously. No doubt this limiting procedure is of a very preliminary character, pending a more profound modification of quantum electrodynamics (which may perhaps bring the auxiliary masses into connexion with the observed finite masses of the particles); but for the time being it not only serves the purpose of making the results of quantum electrodynamics unambiguous, but also it gives results which have the correct relativistic transformation properties. Its application is a necessity when quantum electrodynamics is applied to the controversial problems which diverge in the ordinary theory. It is a satisfactory feature that if regularization is applied to electromagnetic self-energies, it appears that these diverge only logarithmically for all particles so far

considered (namely, spin 0, ½, 1) and are therefore presumably very small.

This result is of interest for meson theory. The charge symmetry of nuclear forces requires very nearly equal masses for the charged meson and the neutretto, and this can only be the case if the electromagnetic self-energy of the former is very small.

We are indebted to Prof. Pauli for communicating to us his manuscript on regularization.

W. HEITLER

Dublin Institute for Advanced Studies.

J. MCCONNELL

St. Patrick's College, Maynooth.
May 10.

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SUSPENSIONS AND SEDIMENTATION

A DISCUSSION on the subjects of suspensions and sedimentation, arranged jointly by the Chemical Society and the British Rheologists' Club, took place during May 6–7 at the Washington Singer Laboratories of the University College of South-West England, Exeter. The chair at each session was taken alternately by Mr. J. Pryce-Jones and Mr. A. de Waele.

The scope of the discussion included the properties of model systems as well as of less well-defined systems of immediate practical, industrial or biological significance. In view of the generally recognized importance of a proper understanding of the factors which influence the properties of suspensions, it is surprising to find that little systematic research has been conducted on elementary systems which are rigidly defined. Many results of, for example, viscosity measurements of colloidal suspensions have been reported; but workers have seldom specified accurately the shape, size-distribution, surface reaction and hydration of the particles, presumably because of the difficulty of measuring them. Several investigations have, in the past, been made on suspensions of larger particles, some characteristics of which could be observed microscopically; but the varying results indicate that the factors influencing the viscosity of suspensions are not fully understood.

The simplest systems consist of uniformly sized, hard, non-interacting spherical particles suspended in an inert liquid (that is, inert towards the solid phase), and it was to elementary systems of this type that the contributions of H. de Bruijn and of R. L. Whitmore and S. G. Ward referred.

Dr. H. de Bruijn described a method of preparing model suspensions of glass spheres within the size-range of 2–200 microns and reported results obtained by measuring, in capillary viscometers, the apparent viscosity of suspensions of the spheres in an aqueous solution of mercuric nitrate and nitric acid of the same density as the glass. He found that the sigma phenomenon is strongly dependent upon the volumetric concentration of the solid phase, and that it occurs only above certain concentrations. The sigma coefficient is, therefore, a function of the concentration of the suspension as well as of the relative fluidity. He suggested that the sigma phenomenon is due to mechanical interaction of the particles within a flowing system, and that this interaction causes a movement of the particles perpendicular to the plane of shear. Near the walls of the retaining vessel this perpendicular movement can be in one direction only and therefore causes a shift of the particles away from the walls. With this suggestion in mind, the theory proposed by Dix and Scott Blair[1] was extended and an expression for the sigma phenomenon was obtained which explained satisfactorily the dependence of the phenomenon on the concentration of the solid phase. The work described is continuing.

It is an interesting fact that the relation between the relative viscosity, η_r, and the volumetric concentration, c, of the solid phase of a suspension, as developed mathematically by Einstein[2]:

$$\eta_r = \frac{\eta}{\eta_0} = 1 + 2{\cdot}5\,c,$$

where η_0 is the viscosity of the liquid and η that of the suspension, depends for its experimental confirmation almost entirely upon the results of Eirich, Bunzl and Margaretha[3], who used glass spheres (size-ratio 1·6 : 1), fungal spores (size-ratio 1·42 : 1) and yeast organisms of unspecified size range. Mr. R. L. Whitmore and Prof. S. G. Ward reviewed published relationships between the relative viscosity and volume concentration of granular particles and described work on rigidly defined systems, one object of which was to test the theoretical and empirical relationships reviewed. They described initial experiments using smooth spheres of a methyl methacrylate polymer suspended in an aqueous solution of lead nitrate and glycerol with the addition of a small proportion of dispersing agent to inhibit flocculation. The liquid had a viscosity of about 6 centipoises, and its density was equal to that of the spheres. The apparent viscosity of the suspensions was determined using a rising sphere method with hard plastic spheres of densities between 1·15 and 1·18 gm. per ml., suitable corrections for wall effect being made. As the result of several experiments with stable suspensions of various concentrations of particles of size-ratios varying from 1·17 : 1 to 2·74 : 1 within the size-range of 28–208 microns, it was concluded that the relative viscosity of a suspension of hard, smooth, non-interacting spheres is independent of the rate of shear up to volume concentrations of 30 per cent; is independent of the absolute size of the spheres; is independent of the viscosity of the suspending liquid; but is dependent upon the size distribution of the spheres, decreasing with increasing size-range to a constant value.

It is difficult to compare these results with those of other workers who, in general, have not defined with sufficient accuracy the size-distribution of the disperse solid phase. The results were, however, compared with those obtained experimentally by Vand[4], by Eirich, Bunzl and Margaretha[3], and by Eilers[5], and those deduced empirically by Philipoff and Hess[6] and by Arrhenius[7], and a satisfactory agreement was demonstrated.

Mr. P. G. W. Hawksley dealt with sedimentation of non-flocculated suspensions. Consideration of the process of sedimentation indicates that two retarding

forces—which may be added to the Stokes resistance for a single sphere—influence sedimentation. There is, first of all, a retardation due to the *presence* of other particles which is similar to the increase in apparent viscosity of suspensions with concentration; and secondly, a retardation arising from the *motion* of other particles which results, at moderate concentrations, in the effective buoyancy being equal to the suspension density. Thus the settling-rate, U_r, of a suspension relative to the settling-rate of a single constituent particle is

$$U_r = \frac{(1 - c^2)}{\eta_r},$$

where η_r is the effective relative viscosity in sedimentation, which differs from the measured bulk viscosity at moderate concentration because collisions are absent, and in dilute solutions because the velocity gradient differs. If, however, a theoretical viscosity relation due to Vand[4], from which the collision term has been omitted, is used for the relative viscosity, the resulting relationship,

$$U_r = (1 - c)^2 \exp\left(\frac{-kc}{1 - 0{\cdot}609c}\right),$$

is found to fit published data on the settling of spheres at concentrations of 7–80 per cent with a value of k not significantly different from the theoretical value of 2·5 obtained by Einstein and others. With non-spherical particles k, as may be expected, is greater than 2·5. At very low concentrations, the relation worked out by Burgers[5] is probably applicable.

Dr. E. R. Winter and Mr. A. J. Hughes presented a paper dealing with the viscosity and settlement of precipitated calcium carbonate in organic liquids, particularly glycerol, and in water. They pointed out the importance of preparing the glycerol pastes in such a way that only the minimum of energy is put into the system and, in order to reduce the chance of permanent rheological breakdown of the material, prefer to mix the paste at about 100° C., at which temperature the viscosity of glycerol is about one-hundredth of its viscosity at 20° C. The measurements were made in a coaxial cone viscometer and in a capillary viscometer; reasonable agreement was obtained even when using suspensions exhibiting anomalous characteristics. In no case, however, were they able to detect a yield value, and the non-Newtonian behaviour was characterized by a variation in apparent viscosity with the rate of shear. These workers found some advantage in using 'fluidity' instead of 'viscosity' (of which it is the reciprocal). They found that the degree of anomaly increases with decreasing temperature, with increasing viscosity of the liquid and with decreasing average particle-size. By extrapolating their apparent viscosity results to zero rate of shear, they deduced empirically that, for glycerol suspensions, the proportionality constant between volume concentration and apparent viscosity at infinite dilution (k in Einstein's relationship) is proportional to the square root of the specific surface of the calcium carbonate. Similar effects were found when the glycerol was replaced by oleic acid or linseed oil, but paraffin oils gave highly flocculated suspensions exhibiting plastic properties; these highly flocculated suspensions produced free-flowing pastes on the addition of a trace of oleic acid. They also found that the flocculated aqueous chalk pastes exhibit anomalous properties, that the apparent viscosity is a function of the degree of flocculation and that an increase in the proportion of fines in the calcium carbonate, or an increase in temperature of the paste, increases its apparent viscosity. The addition of electrolytes in suitable proportions was shown to deflocculate the paste and confer normality of behaviour.

Mr. E. G. J. Willing described experiments carried out in an investigation, still proceeding, on the sedimentation volume of powders in liquids. There is no general agreement on reasons which have been put forward to account for the different settled volumes occupied by the same weight of a given material in different liquids, although it is agreed that the presence of water has an important effect. Mr. Willing's experiments were made on precipitated calcium carbonate from which all traces of water had been removed. The dry material was added to selected pure, dry, organic liquids, and it was found that in all cases the smallest sedimentation volume was obtained in water and the largest in carbon tetrachloride. The same order in sedimentation volumes was found when 0·5 per cent water was added to each liquid; but there were wider variations from liquid to liquid. From a consideration of the reduction in free surface energy of the calcium carbonate produced by the addition of small proportions of water, he concluded that the interfacial tension of the organic liquids against water has a direct effect on the sedimentation volume of the powder.

Dr. P. Eggleton reviewed published work on the subject of rheology of blood. The apparent viscosity of blood falls as its rate of flow increases, and, for a given rate of flow, falls with decreasing tube diameter, the latter effect beginning to appear for tube diameters about forty to fifty times that of red blood corpuscles. These effects may be accounted for by the tendency, easily observed under a microscope, for red blood cells to concentrate in the axis of the moving stream of blood, leaving a layer of pure plasma adjacent to the walls. If this effect were proportional in magnitude to the rate of flow, the anomaly would be explained. Dr. Eggleton pointed out, however, that Whittaker and Winton[9] found the apparent viscosity of blood flowing in capillaries of the hind limbs of the dog was only half the apparent viscosity measured in glass tubes. No worker has yet, however, been able to force blood through glass tubes of the same diameter as a blood capillary.

Dr. Eggleton discussed, also, the sedimentation of blood corpuscles *in vitro* and referred in particular to the expression obtained by Whittington[10] for the rate of sedimentation of cells in plasma, based on the well-known fact that agglutination of the cells into clumps is the most important factor influencing the rate. It was suggested that the expression, which involves the viscosity and density of the plasma and the whole blood, may have a doubtful theoretical basis.

Other contributions included a short account by Dr. E. W. J. Mardles and Mr. A. de Waele on sedimentation volumes of suspensions in centrifuge tubes, and a description by Mr. R. A. Acton Taylor of the use of the pendulum method for determining settling rates of suspensions.

The fact that the lively discussions following each paper had to be restricted by the chairman indicates the interest which the papers aroused. A review, such as this, of the proceedings is too short to bring out more than a few of the important points raised, and it is to be hoped that the authors will arrange

for publication in full of the papers presented at the discussion. STACEY G. WARD

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NATIONAL INSTITUTE OF INDUSTRIAL PSYCHOLOGY

THE annual conference of the National Institute of Industrial Psychology was held at Buxton during April 29–May 2, and took as its theme the job and its day-to-day reality. This theme was set in a wide framework by Sir George Schuster, chairman of the Human Factor's Panel of the Committee on Industrial Productivity, who opened the conference by stating that the job is the essential basis of the good and satisfactory life, and that we could do little unless our attitude was based on a belief that life had purpose and meaning.

Concentrating on the two questions: (1) Could the industrial task be accepted as a satisfactory part of human life?; (2) How could modern industrial employment be made a free activity?, Sir George stated that too many sweeping generalizations had been made in answer and there was urgent need to study the job, how it affected different people, how it could be designed to fit the individual worker and how monotony and drudgery could be relieved. Where work could not be made satisfying of itself, attempts should be made to ensure satisfaction in its other aspects. The most important task to-day was to seek out and remove the obstructive influences in industry that checked the will to work.

Taking the chair at the second session, the president of the Institute, Lord Piercy, explained that the Conference would be addressed in turn by three manual workers from the steel, cotton and coal-mining industries. Each speaker gave a detailed account of his job as a furnaceman, weaver or miner, and Prof. Rex Knight then related these three descriptions to the work of the industrial psychologist. There appeared to be four main points at which the findings and methods of the industrial psychologist had a bearing on their work. With better selection, labour turnover and training wastage would be reduced, while whether a boy was going to be a smelter, a weaver or a miner, effective training methods should be introduced. Working conditions should be made as comfortable as possible, and attention to the improvement of personal relations had been promoted by the industrial psychologists through attitude-surveys, grievance-interviews, recommendation-forms and other techniques.

At the next session, the three manual workers were re-introduced by Sir Ronald Adam, chairman of the Institute, who stated that the three speakers would describe the satisfactions they obtained from their work. Their accounts were related to those of other industrial workers by Charles Madge, social development officer to the Stevenage Development Corporation. While the three speakers might derive considerable satisfaction from their work, it was questionable whether the majority of workers had comparable satisfactions. Quoting the results obtained from a survey which he had directed at three large factories, Mr. Madge declared that three out of every four workers were generally satisfied with their jobs. There was a difference between the satisfactions described by skilled and unskilled men; skilled men liked the variety of their work, the pay and the responsibility; the unskilled liked easy work and good conditions. Many surveys showed that only between one-tenth and one-fifth of workers were interested in the trade unions, works councils, clubs and evening classes. The 'feel' of the work was also important and was a primitive and instinctive satisfaction which obtained in pre-industrial eras and had been carried over into the 'heavy' industries, the earliest to be developed. These old heavy industries contrasted strongly with the modern 'light' industries, in which little of this 'feel' was needed and which led to a certain degree of dissatisfaction in the worker.

The closing address was given by Mr. E. P. Harries, the T.U.C. member of the Human Factors Panel of the Committee on Industrial Productivity, who declared that social justice and individual satisfaction could only be achieved through the unity of free men. Confidence was badly needed in industry to provide an atmosphere of spiritual development in which all would obtain lasting satisfaction in their work.

T. H. HAWKINS

FIFTH BRITISH EMPIRE FORESTRY CONFERENCE

THE First British Forestry Conference was held in London in 1920; it practically heralded the new Forestry Commission which had been set up under the 1919 Parliament Forestry Bill and placed it in the saddle under the presidency of that very able and keen landowner, the late Lord Lovat. One of the not least important subjects under consideration at the first meeting was forestry education, and it is interesting to contrast the position held by forest education in the Empire at that date with that of to-day. One of the outcomes of this first Conference was the inauguration of the Imperial Forestry Institute at Oxford four years later.

The Fifth Conference was conducted in London at Church House, Westminster, on June 15, 1947 (London: H.M. Stationery Office, 1948. 10*s.*); the Ministers of State for Agriculture and for Scotland, Mr. Tom Williams and Mr. Joseph Westwood, opened the proceedings, and were supported by other Cabinet Ministers and by Forestry Commissioners. The two Secretaries of State were elected presidents, Lord Robinson chairman, with Mr. D. R. Cameron (Canada), Mr. A. P. F. Hamilton (India) and Dr. F. Y. Henderson as vice-chairmen. The delegates and associate delegates came from all over the Empire and included one guest from the United States and two from the Forestry Branch of the Food and Agriculture Organisation of the United Nations.

Excursions were made to certain of the areas afforested by the Forestry Commission since they started operations in 1920, both in England and Scotland, and some privately owned woods were included in the tour. Factories connected with wood utilization were also visited, including the Forest Products Research Laboratory, Princes Risborough.

Thirty-six forest authorities presented statements on Empire forests and the War. These were not merely of interest, but were particularly valuable as a record on such matters as: the areas of land under forest; total volume of standing timber and of increment; output of home-grown wood; imports and exports for pre-war years and for each war year; the effect of war-time exploitation on forest capital and future increment (the latter more or less guesswork in most cases); and, lastly, the lessons to be learned from war-time experience—especially the often quite unnecessary and unjustifiable war-time extravagance. The data acquired have been analysed and summarized by the Central Statistical Office and printed as a publication entitled "Empire Forests and the War. A Digest of Statistics prepared by the Fifth British Empire Forestry Conference" (H.M. Stationery Office).

The subject of land-use came under the consideration of one of the sections of the Conference. In the Fourth Conference held in South Africa in 1935, under resolution No. 2 the Governments of the Empire were urged to maintain under vegetative cover catchment areas and other lands particularly liable to desiccation and erosion. This matter had first received public world-attention at the World Forestry Congress held in Rome in 1926 and was again brought up at the Second World Forestry Congress in Budapest in 1936. Those who have been studying this problem for many years know how little has been done as a result of the resolutions put forward on the subject at these Congresses.

One step, however, inaugurated in the United States, has made a start on promising lines, and that is the appointment of Soil Conservation Committees; several similar bodies are also now working in several British Colonies and some of the Dominions. But this commencement, so far as it has gone, has been more or less confined to agriculture and its improvement in various ways; the real root of the matter, which rests in the maintenance of the forests of certain definite parts of the catchment areas of the world in the interests of agriculture, has not yet been really touched upon.

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION, AUSTRALIA

REFERENCE was made in *Nature* of April 30, p. 671, to impending changes in the conduct of Government research in Australia. As from May 19, 1949, the Australian Council for Scientific and Industrial Research will be known as the Commonwealth Scientific and Industrial Research Organisation. This announcement was made on behalf of the Australian Government by the Hon. J. J. Dedman, Minister in Charge, who also announced the following appointments to the Executive of the Organisation: the chairman will be Dr. Ian Clunies Ross; the chief executive officer, Dr. F. W. G. White. Both were previously members of the Executive of the Commonwealth Council for Scientific and Industrial Research. They succeed Sir David Rivett and Dr. A. E. V. Richardson respectively. The new appointments will be for seven years. The third full-time executive member will be Dr. S. H. Bastow, formerly chief of the Division of Tribophysics, whose appointment will be for five years. The fourth member will be Mr. D. A. Mountjoy, whose three-year term expires next November. Mr. H. J. Goodes, assistant secretary, Commonwealth Treasury, has been appointed for three years to the fifth seat on the Executive.

Mr. Dedman said that he looked forward with confidence to the new Organisation continuing unbroken the long and honourable record of service which the Council had given to the Commonwealth. While the recent rapid expansion and widespread ramifications of the Council's work had led the Government to bring into being a new form of organisation more suited to present-day needs and responsibility, every care had been taken to preserve that freedom and initiative so essential for effective scientific work. All rights and privileges of officers of the old body would be safeguarded in the new, and Mr. Dedman said he had no doubt that the staff would find unimpaired the conditions of service and the high traditions built up over the past two decades.

Mr. Dedman paid a warm tribute to all those members of the former Council and its State committees whose disinterested service from its inception had contributed in marked degree to the success which had rewarded the Council's work. He had greatly appreciated the free and generous offer of the members of the Council to serve on the Advisory Council of the new Organisation, and, in the expectation that members of the State Committees would display a similar willingness, he would shortly extend an invitation, on behalf of the Government, to all of them to do so. It was particularly pleasing to him personally and to the Government that Sir David Rivett, while laying down the cares of his present office as chairman of the Council, had consented to act as chairman of the new Advisory Council. On behalf of the Prime Minister and the Government of the Commonwealth, Mr. Dedman wished to place on record the substantial debt owed to Sir David Rivett and Dr. A. E. V. Richardson.

Sir David, as chief executive officer of the Council for Scientific and Industrial Research for just on twenty years and more recently as chairman, had become identified not only with the Council which, with its successor body, would always stand as a monument to his untiring care and wise direction, but also with Australian science in general. Sir David had seen the Council grow from small and uncertain beginnings to a great organisation of truly national proportions with an international reputation. On his retirement, Sir David would have the satisfaction of knowing that he carried with him the affection of his thousands of colleagues and the esteem of the whole community.

Dr. Richardson, first as member of the Executive committee of the Council, and later as deputy chief executive officer, and finally as chief executive officer, had brought to the Council an unrivalled knowledge of the problems of Australian agriculture, and a wide experience and sound judgment which had influenced all the Council's activities. He had played a major part in the development of the Council's work in the plant and animal industries than which none had yielded results of greater value to the Commonwealth. As dean of the Faculty of Agriculture in the University of Melbourne, as first director and creator of the Waite Institute in South Australia, and as chief executive officer of the Council for Scientific and Industrial Research, Dr. Richardson's name would always be associated with the development of Australian agricultural science.

APPOINTMENTS VACANT

APPLICATIONS are invited for the following appointments on or before the dates mentioned :

ASSISTANT LECTURER IN ZOOLOGY (Science degree with special qualifications and post-graduate experience in Entomology or Helminthology), a RESEARCH ASSISTANT IN ZOOLOGY (specially qualified in Entomology or Helminthology), and a DEMONSTRATOR AND FIELD ASSISTANT IN THE BOTANY DEPARTMENT (Science degree with special qualifications in Botany)—The Secretary, West of Scotland Agricultural College, 6 Blythswood Square, Glasgow C.2 (August 13).

LECTURER IN BIOCHEMISTRY in the Department of Physiology—The Secretary, Royal Veterinary College and Hospital, Royal College Street, London, N.W.1 (August 15).

LECTURER IN CIVIL ENGINEERING, and a CLINICAL PHOTOGRAPHER in the General Infirmary—The Registrar, The University, Leeds 2 (August 18).

LECTURER IN STATISTICS in the Department of Mathematics in the United College—The Secretary, The University, St. Andrews (August 20).

PHYSICIST to work on scintillation counting and its clinical applications, and LABORATORY TECHNICIANS (2) to assist in work on the applications of nuclear physics in medicine—The House Governor and Secretary, Royal Cancer Hospital, Fulham Road, London, S.W.3 (August 22).

ORGANIC CHEMISTS (Ref. F.497/49A), CHEMICAL ENGINEERS (Ref. F.496/49A), and an INSTRUMENT ENGINEER (Ref. 258/49A)—Technical and Scientific Register (K), York House, Kingsway, London, W.C.2, quoting appropriate Ref. No. (August 22).

SENIOR SCIENTIFIC OFFICER (C.473/49A), for work including design of tunnel air circuits, particularly assessment of characteristics of fans and compressors, and SENIOR SCIENTIFIC OFFICERS and SCIENTIFIC OFFICERS (C.474/49A), for work including design of supersonic nozzles and other parts of tunnel air circuits, planning detailed requirements for instrumentation and observation, calibration and operation of plant for experimental work and aircraft development—Technical and Scientific Register (K), York House, Kingsway, London, W.C.2, quoting appropriate Ref. No. (August 27).

KEEPER OF ART and a KEEPER OF ANTIQUITIES—The Director, Museum and Art Gallery, New Walk, Leicester (August 27).

ASSISTANT LECTURER IN CHEMICAL ENGINEERING, an ASSISTANT LECTURER IN METALLURGY, and an ASSISTANT LECTURER IN REFRACTORY MATERIALS—The Registrar, The University, Leeds 2 (August 27).

ASSISTANT LECTURER IN ELECTRICAL ENGINEERING at Denbighshire Technical College, Wrexham—The Director of Education, Education Offices, Ruthin (August 28).

LECTURER or ASSISTANT LECTURER IN THE DEPARTMENT OF CHEMISTRY to teach Physical Chemistry—The Registrar, University College, Hull (August 29).

DIRECTOR FOR THE CENTRAL DRUG RESEARCH INSTITUTE, Lucknow—The Secretary, Council of Scientific and Industrial Research, "P" Block, Raisina Road, New Delhi, India (August 31).

PRINCIPAL SCIENTIFIC OFFICER and SENIOR SCIENTIFIC OFFICER for research and development work on photography from high-speed aircraft and on air survey photography, and a SCIENTIFIC OFFICER for work on automatic pilots and blind landing—Technical and Scientific Register (K), York House, Kingsway, London, W.C.2, quoting A.43/49A (August 31).

LECTURER IN CHEMISTRY, with special qualifications in Organic Chemistry—The Secretary, The University, Birmingham 3 (August 31).

ASSISTANT LECTURER IN THE DEPARTMENT OF VETERINARY ANATOMY, and an ASSISTANT LECTURER IN VETERINARY BACTERIOLOGY—The Registrar, The University, Liverpool (September 3).

PRINCIPAL SCIENTIFIC OFFICERS at the Royal Aircraft Establishment, Farnborough : (*a*) C.470/49A, to carry out and supervise research into fatigue of aircraft structures, (*b*) C.471/49A, to take charge of section carrying out research into behaviour of materials and structural elements for use of aircraft designers, (*c*) C.472/49A, to carry out and supervise research into fundamental theory of structures, primarily from standpoint of aircraft—Technical and Scientific Register (K), York House, Kingsway, London, W.C.2, quoting appropriate Ref. No. (September 5).

PRINCIPAL SCIENTIFIC OFFICERS or SENIOR SCIENTIFIC OFFICERS (2) for a Ministry of Supply Establishment in Bucks : (*a*) C.476/49A, for control of section studying problems of liquid rocket combustion chambers, atomizers, nozzles, etc., (*b*) C.477/49A, for supervision of team studying fuel supply problems of liquid rocket motors—Technical and Scientific Register (K), York House, Kingsway, London, W.C.2, quoting appropriate Ref. No. (September 8).

ASSISTANT LECTURER IN THE DEPARTMENT OF OCEANOGRAPHY—The Registrar, The University, Liverpool (September 10).

LECTURER IN INORGANIC CHEMISTRY—The Secretary and Registrar, University College of North Wales, Bangor (September 10).

SCIENTIFIC INSTRUMENT MAKER and LABORATORY TECHNICIAN (main duties will be the construction of physical research apparatus), and a LABORATORY TECHNICIAN (duties will include the maintenance and operation of diesel and electrical gas compressors)—The Secretary, The University, St. Andrews (September 20).

CHAIR OF ZOOLOGY at Raffles College, Singapore—The Secretary, Inter-University Council for Higher Education in the Colonies, 8 Park Street, London, W.1 (September 30).

RESEARCH CHAIR OF WOOL TEXTILE ENGINEERING—The Registrar, The University, Leeds 2 (September 30).

HISTOLOGY TECHNICIAN, to take charge of the technical work in the Department of Pathology—The Registrar, University, Bristol 8 (October 8).

TECHNICAL ASSISTANT by East Africa High Commission for Desert Locust Survey—Crown Agents for the Colonies, 4 Millbank, London, S.W.1, quoting M/X/22726/3F.

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RESPONSIBLE LECTURER IN SCIENCE—The Principal, County Mining and Technical School, Nuneaton.

DEMONSTRATOR IN POULTRY HUSBANDRY—The Registrar, The University, Nottingham.

LABORATORY TECHNICIAN—The Director, Radiotherapeutic Research Unit, Hammersmith Hospital, Ducane Road, London, W.12, marking envelope 'Histology Technician'.

SENIOR ASSISTANT IN PHYSIOLOGY—The Registrar, Municipal College, Portsmouth.

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(*not included in the monthly Books Supplement*)

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LETTERS TO THE EDITORS

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Magnetic Properties of Metal Single Crystals at Low Temperatures

THE striking periodic field dependence of susceptibility found by de Haas and van Alphen[1] in bismuth was for a long time regarded as just another anomalous property of bismuth, and although the theory of Peierls[2], Blackman[3] and Landau[4] suggested that it was an effect to be expected in principle for all metals, it was believed that it was only in bismuth that the conditions were suitable for the effect to be observable in practice. The recent discovery of very similar behaviour in zinc by Marcus[5] followed by the more detailed experiments of Sydoriak and Robinson[6], and Mackinnon[7], suggested, however, that the effect might occur in other metals too, and a systematic investigation has accordingly been undertaken.

In preliminary experiments on the magnetic anisotropy of single crystals, measured by the couple acting in a uniform magnetic field, the de Haas–van Alphen effect has been found in gallium and tin, while negative results have been obtained for antimony, indium, lead and mercury in fields up to 9,500 gauss and at temperatures down to 1·4° K. Negative results have previously been reported for thallium[6] and cadmium[6,7] also. Some typical curves illustrating the behaviour of gallium and tin are shown in Figs. 1 and 2. These are based on measurements in which a crystal was suspended with its principal axis horizontal and at angle ψ to the magnetic field, which could be rotated in a horizontal plane. The following

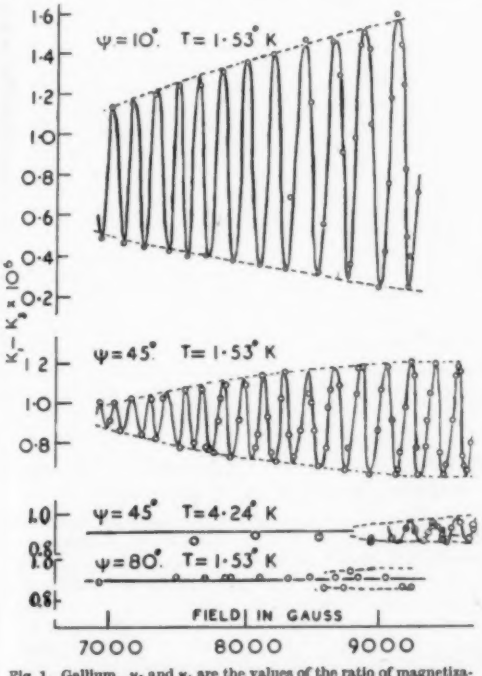

Fig. 1. Gallium. $\varkappa_2$ and $\varkappa_1$ are the values of the ratio of magnetization to field along, and perpendicular to, the principal axis

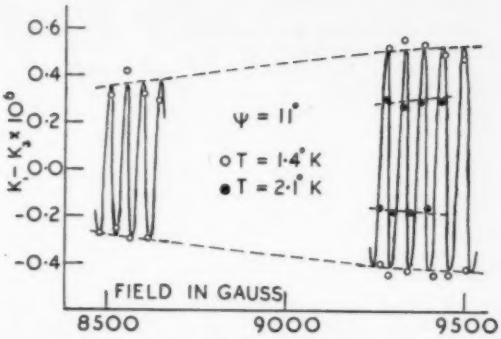

Fig. 2. Tin. $\varkappa_2$ and $\varkappa_1$, as in Fig. 1. The experimental points are the observed maxima and minima, and the graph of the oscillations is schematic only; at 2·1° K. only the envelope is indicated. On account of the difficulties explained in the text, the experimental accuracy for tin is poorer than for gallium

features should be noted: (1) the effect becomes more marked as ψ is reduced, and the effect is practically absent for $\psi = 80°$; (2) the period of the oscillations—about 200 gauss for gallium and 40 gauss for tin (at 9,000 gauss and low ψ)—is much smaller than the 2,000 gauss or so characteristic of zinc or bismuth; (3) the influence of temperature is similar to that previously found in zinc and bismuth; as the temperature is raised, the period and phase of the oscillations are unchanged, but the amplitude decreases rapidly; the effect in tin fades out somewhere between 2° K. and 4·2° K., but in gallium is still feebly present at 4·2° K.

Landau has shown that the variable part of the susceptibility (and the anisotropy) at temperature T and field H is proportional to

$$\frac{T_0 T}{(\beta H)^{\frac{3}{2}}} \exp\left[-2\pi^2 kT/\beta H\right] \sin\left(\frac{2\pi kT_0}{\beta H} - \frac{\pi}{4}\right),$$

or in some cases is the sum of several such terms, though usually a single term, that with the greatest β, is dominant. In this expression, T_0 is the degeneracy temperature of the electrons and β an effective electronic magnetic moment, given by eh/mc, where m is a suitable effective electronic mass depending on crystal orientation. The fact that the effect is absent for H perpendicular to the principal axis means that m_1, the effective mass for motion perpendicular to the principal axis, is several times smaller than m_2, the effective mass parallel to the principal axis; the value of the ratio (m_1/m_2) cannot, however, be estimated reliably from the experiments so far completed. (We have, for simplicity, introduced only a single mass m_1 in the plane perpendicular to the principal axis. For gallium, which is orthorhombic (though very nearly tetragonal), and zinc, which is hexagonal, however, two masses m_1 and m_2 are needed. More detailed experiments are required to distinguish experimentally between m_1 and m_2; so far as the table is concerned, m_1 should really be replaced by $(m_1 m_2)^{1/2}$ for gallium and zinc.)

The very short periods of the oscillations are connected with values of $m_1 T_0$ much higher than in zinc and bismuth, and from the periodicity, values of $m_1 T_0$ of about $40m_0$ for gallium and $250m_0$ for tin can be estimated, compared with about $2m_0$ for zinc (m_0 is the ordinary electronic mass). It may be mentioned that the argument of the sine term is of order 75π for gallium, 400π for tin, but only 3π for zinc at 9,000 gauss. Values of m_1 may be estimated (*a*) from

the temperature variation of amplitude, (*b*) from the shape of the envelope at a single temperature, and (*c*) from various comparisons between curves for different ψ at the same temperature. As in zinc and bismuth, the various estimates do not agree very well, and the discrepancy is in the sense that the temperature variation is not so rapid as the theory predicts. The various estimates of m_1 and the corresponding estimates of T_0 are collected in the table, together with figures for zinc (based on the work of Mackinnon[7]) for comparison; for bismuth more parameters are required to interpret the data, and no simple quantitative comparison is possible.

	m_1/m_0			T_0 ° K.		
	(*a*)	(*b*)	(*c*)	(*a*)	(*b*)	(*c*)
Gallium	0·06	0·16	0·17	700	270	250
Tin	0·1	0·3	0·6	2500	800	400
Zinc	0·008	0·015	0·012	250	130	160

(*b* and *c* at 4·24° K.)

From an experimental point of view, the measurements are complicated, particularly with tin, by the very short period of the oscillations and by the heavy eddy-current damping of any motion of the metal in the magnetic field; in view of this, and since it is not certain that the gallium specimen was entirely a single crystal, the results illustrated and the conclusions drawn from them must be regarded as illustrating only the general nature of the phenomena, until more thorough measurements have been completed. It should be noted, too, that negative results must be regarded with caution, since the apparent absence of field-dependence may be due to slight inhomogeneity of the field or the specimen (for example, variations of crystal orientation or fluctuations of impurity concentration), which might smooth out oscillations of very short period.

Note added in proof. The de Haas – van Alphen effect has just been found also along the hexagonal axis of a graphite crystal; the characteristic features are intermediate between those of zinc and gallium.

D. Shoenberg

Royal Society Mond Laboratory,
Cambridge. June 23.

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[3] Blackman, *Proc. Roy. Soc.*, A, **166**, 1 (1938).
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Absence of Delayed γ—γ Coincidences in the Decay of Hafnium-181

β-Emission by hafnium-181 leads to a 20-microsecond metastable state of tantalum-181 [1]. This has been studied by observing delayed coincidences between the β-rays from hafnium-181 and the radiation emitted in the decay of the metastable state. The delayed radiation consists of cascade γ-rays of 0·13 and 0·47 MeV. and the corresponding conversion electrons[2,3,4]. Beneš *et al.*[4] have reported that sources of hafnium-181 give rise also to delayed γ—γ coincidences and have proposed a decay scheme showing a 0·34-MeV. γ-transition preceding the metastable state of tantalum-181. The other workers[1,2,3] have not reported delayed γ—γ coincidences, and this implies a decay scheme in which β-emission by hafnium-181 leads directly to the metastable state. We have carried out recently a re-examination of hafnium-181 for delayed γ—γ coincidences with a negative result.

In our test for delayed coincidences, we used the integral recorder described earlier[2,3]. The hafnium source was placed between two Geiger counters. From one counter (counter *A*) a pulse 38 microseconds in length passed to the coincidence stage, while the pulse from the other counter (counter *B*) was 0·3 microsecond in length. An anti-coincidence circuit of 2 microseconds resolving time, actuated from counter *A*, was used to suppress instantaneous coincidences. The two counters used each had copper cathodes 5 cm. long and 2·5 cm. in diameter (active anode length, 3 cm.) with end window of aluminium 7 mgm./cm.² thick. Both windows were covered with 360 mgm./cm.² lead sheet, and the two counters were mounted with the lead sheets facing each other 3 mm. apart. The source between the lead sheets was stuck to a 2·3 mgm./cm.² aluminium foil. The net efficiencies of the counters for recording individually the γ-transitions known to be present (including the allowance for internal conversion and solid angle) were estimated to be as follows: 0·47 MeV., 0·25 per cent; 0·34 MeV., 0·15 per cent; 0·13 MeV., 0·03 per cent. (The relative net efficiencies were estimated from the construction of the counters, the approximate absolute values of the net efficiencies being then inferred from the counting-rates with and without the lead sheets in position.)

To be detected, a genuine delayed coincidence-rate must exceed the errors in both the total recorded coincidence-rate and the computed random coincidence-rate. If no genuine delayed coincidence-rate is observed, it means that less than a certain fraction of the counts recorded in counter *A* can be followed by delayed rays detectable in counter *B*. The counting-rates of the individual counters in our delayed coincidence experiment were about 50 per sec., and a counting time of 40 hr. gave approximately equal errors in the total recorded coincidence-rate and the computed random-rate. Analysis of the results following a procedure similar to that used in ref. 3 showed that not more than about 0·7 per cent of the counts recorded in counter *A* could be followed by γ-rays, which were detected in counter *B* with a combined net efficiency of 0·3 per cent and delayed with a half-life of 20 microseconds. From this, and the net efficiencies given in the preceding paragraph, it follows that not more than 2 or 3 per cent of the disintegrations of hafnium-181 can take place according to the decay scheme proposed by Beneš *et al.*[4].

D. Walker
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University, Birmingham 15.
March 30.

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[2] Bunyan, Lundby, Ward and Walker, *Proc. Phys. Soc.*, **61**, 300 (1948).
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Modified Ionization Chamber for Study of Angular Distribution of Ionizing Particles

A new method of studying the angular distribution of ionizing particles with ionization chambers has been developed here and then applied to the study of the angular distribution of uranium fission fragments produced by fast neutron bombardment. Fig. 1 shows the principle involved. *A* and *B* are the positive and negative plates respectively of a plane parallel-plate ion chamber filled with pure argon gas, in which the negative ion mobility is very much greater than

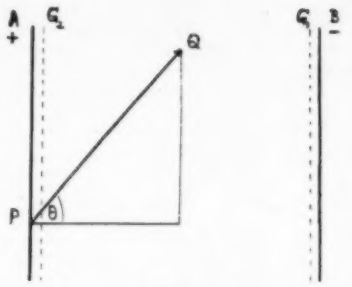

Fig. 1

that of the positive ions. A is lined with a layer of U_3O_8 and bombarded with neutrons. Let PQ be the ion track of a fragment emitted at angle θ to the electric field. The negative ions are collected first, amplified and made to trigger the time-base of a cathode ray tube, and the positive ions are collected afterwards and applied to the Y plates. (Our thanks are due to Dr. A. N. May for suggesting this initial idea.) It is clear that the position of the positive ion pulse on the time-base will give a measure of the projection length of the ion track on the electric field.

If the pulse-height measures the range of the fragment, then $\cos\theta$ is completely defined. Since it is essential that the positive ion pulse be formed only when the ions reach plate B, an electrical screen G, in the form of a grid, is introduced in front of and very near plate B. The screen grid in front of A acts as a 'Frisch' grid to screen the negative ion pulse from the induced charge of the positive ions.

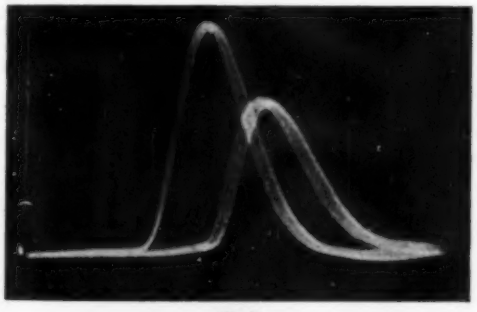

Fig. 2

The photograph (Fig. 2) shows two such pulses corresponding to two different fragments coming out at two different angles. The second shows a fragment of smaller range but emitted at an angle close to the first. The method is reliable to a resolution of 1° at angles greater than 25°; but at smaller angles, due to the slow rise of the pulses, the measurements are less accurate. The angular distribution of the fission fragments using a fast neutron radium–beryllium (400 mc.) howitzer was found to be isotropic.

The method is now being applied to the study of the angular distribution of secondary neutrons from fission, and details will be published elsewhere.

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London.
April 28.

Interpretation of Electron Micrographs Prepared by the Plastic Replica Process

In early work on the electron microscopic study of surfaces by the plastic replica process it was tacitly assumed that the upper surface of the replica, that is, the surface remote from that being examined, is substantially flat (Fig. 1*a*). It has been suspected for some time that this is not so, and the matter has been discussed in a recent paper by Deacon *et al.*[1]; but they have made no direct experimental test. Thus, it might be expected that a normal (unshadowed) replica micrograph would be the result of a superposition of the structure of the surface which had been in contact with the surface to be examined, and that of the upper surface of the replica. If the replica has the shape shown in Fig. 1*b*, artefacts will be introduced by the contour of the upper surface at the places indicated by dotted lines. A micrograph showing just this effect is reproduced in Fig. 2.

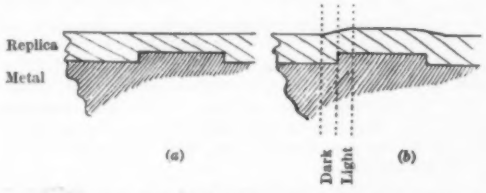
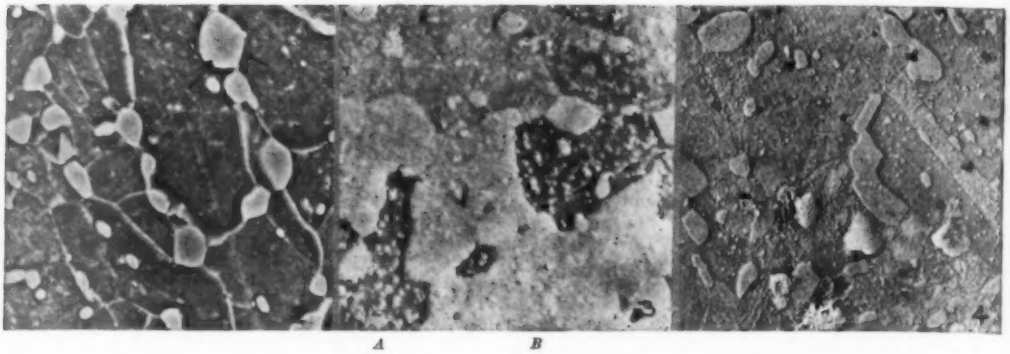


Fig. 1*a*. Section of idealized replica; top surface plane. Thinner portions of replica corresponding to elevations of metal surface appear light in final print, as in Fig. 2

Fig. 1*b*. Actual replica; top surface of similar contour to the surface being studied produces additional effects at parts of the replica indicated by parallel dotted lines

By deposition *in vacuo* of an appropriately thick film of a heavy metal on the surface of the replica which it is desired to study, the so-called shadowing technique, the effects of the structure of the other replica surface on the micrograph may be eliminated. Shadowing is frequently used to increase contrast; but it is also a convenient way of eliminating the disturbing influence of a non-planar upper surface to the replica.

Although the effect can be eliminated in this way, considerable interest is attached to a knowledge of the structure of the upper surface, since it may play an important part in the interpretation of normal, unshadowed replicas. Some experiments have therefore been made to study this upper surface by depositing chromium on it before the replica was stripped from the underlying metal. Fig. 3 shows a micrograph prepared in this way from a tempered carbon–steel specimen. A micrograph of a normal 'Formvar' replica of the same specimen is shown in Fig. 2, and a shadowed replica with the chromium deposited on the surface which was originally in contact with the metal surface is reproduced in Fig. 4. The amount of detail characteristic of the metal surface which persists through to the upper surface of the replica (Fig. 3) is quite striking; the carbide particles are still clearly visible although the edges are generally more rounded. This micrograph clearly demonstrates that the surface is far from plane. The micrograph confirms also that the light and shade effects seen at the edges of the large particles in Fig. 2 are, at least in part, an artefact introduced in the way illustrated in Fig. 1*b*. The variations in tone between different background areas should be noted. These should not here be due to variations in replica thick-



A B

Fig. 2. Normal, unshadowed plastic replica tempered 0·6 per cent carbon steel. Artefacts associated with the large carbide particles indicated by arrows. Normal positive reproduction

Fig. 3. Plastic replica. Upper surface heavily shadowed with chromium at angle of inclination of 12° to surface. Note difference in tone in areas *A* and *B*. Normal positive reproduction

Fig. 4. Plastic replica shadowed on surface originally in contact with the metal. Shadowing angle 20°. The artefacts shown in Fig. 2 are no longer visible. Normal positive reproduction

ness, since the chromium deposit should be sufficiently thick to suppress their effects. They are probably due to differences in the deposition of chromium resulting from structural detail too fine to be visible in the reproduction.

All replicas were prepared from ½ per cent 'Formvar' solutions. The 'Formvar' film was 'backed' with a nitrocellulose film to facilitate stripping, and in the case of replicas shadowed on the upper surface this backing film was put on after the deposition of chromium. The nitrocellulose was afterwards dissolved away in amyl acetate. The chromium deposit, where used, had an average thickness of 60–80 A.

Useful information on the main features of a structure may be obtained from normal, unshadowed replicas; but it is evident from this investigation that the shadowing technique must be employed in order to obtain faithful records of the finer details of a surface from a plastic replica.

J. TROTTER

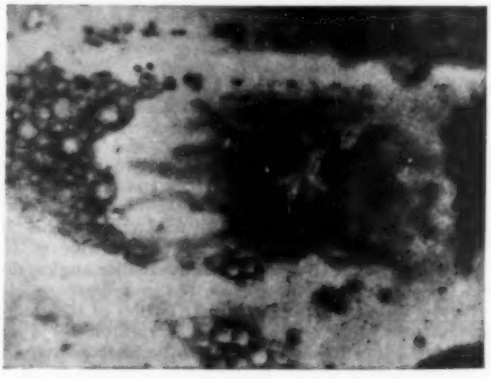
Metallurgy Division,
National Physical Laboratory,
Teddington, Middlesex.
Feb. 17.

[1] Deacon, Ellis, Cross and Sennett, *J. Appl. Phys.*, **19**, 704 (1948).

A Simple Reflecting Microscope

INTEREST in reflecting microscopes has been considerably stimulated in recent years as a result of the development by Burch[1] of instruments of this type with aspheric surfaces. The advantage of the reflecting microscope lies in its complete achromatism, which enables it to be used with ultra-violet, visible or infra-red light, and in its large working distance, which is sufficient for micro-dissection and for viewing objects within furnaces, etc. Burch (*loc. cit.*) has pointed out that reflecting microscopes can be constructed with spherical mirrors. In this way one avoids the trouble of aspherizing the mirrors, and microscopes of this type have been used by Brumberg[2]. Details of design and performance, however, have not been available.

We have constructed a cheap, simple reflecting microscope with spherical mirrors, and the performance is comparable with that of a ¼-in. objective. The optical parts consist of two approximately monocentric aluminized glass mirrors readily available commercially and costing a few tens of pounds. The objective focal length is 5 mm., the N.A. is 0·5, and the working distance 9 mm. Although the central obstruction of the mirror system is as large as 47 per cent of the numerical aperture, we find that the resulting diffraction does not seriously spoil the definition of the image of most biological objects (see accompanying photograph). The objective screws on to any standard microscope, and, with standard tube-length, gives a magnification of × 36; it may, however, be readily adjusted for any other tube-length and magnification, and for any thickness of cover-slip up to 0·5 mm. The field is large, and the corrections, as shown by microscope interferometer, are well within the Rayleigh limit for 2,500 A. light.



Living newt kidney tissue culture cell in metaphase. Photograph × 1,100, with 2,652 A. light, 0·5 N.A. reflector

The objective has been used for photographing with ultra-violet light (see photograph) various living mitotic tissue cultures, focusing being by visible-phase illumination. New objectives of higher N.A. and

smaller central obstruction are being developed, and full details will be published shortly.

We wish to thank Dr. C. R. Burch for much valuable advice given us during this work. Already an objective of 0·55 N.A. with 35 per cent central obstruction has been tested and appears satisfactory.

W. E. Seeds
M. H. F. Wilkins

Wheatstone Physics Laboratory,
and
Medical Research Council,
Biophysics Research Unit,
King's College,
London, W.C.2.

[1] Burch, C. R., *Proc. Phys. Soc.*, **59**, 41 (1947).
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A Transmission-Type Interferometer Microscope

It is well known that the phase-contrast microscope cannot give a faithful representation of optical path-differences as variations of intensity in the image when the detail considered is coarse. This is because light is diffracted by coarse detail through only small angles, and hence the necessary separation of direct and diffracted beams cannot be complete. The edges of large details are therefore emphasized, giving a characteristic appearance to phase-contrast images.

This would be avoided if an interferometer were employed in which two fields of view, one containing the image of the light source only, the other containing the image of the light source with the object superimposed, are caused to interfere with each other. The optical thickness of the object then modifies the phase difference between the two fields and gives rise to intensity variations in the resultant.

A method for realizing such an interferometer, employing only one objective and one condenser, has been developed. The illuminating cone from the condenser (Fig. 1) is intercepted by a nearly plane-parallel glass plate of which the top surface is half-silvered and the bottom surface bears a small, fully silvered central spot. Part of the beam traverses the plate and illuminates the object, and part suffers two internal reflexions and emerges upwards past the object. The diameter of this second beam in the object plane can be made several millimetres, so the presence of the object, if small, does not disturb it.

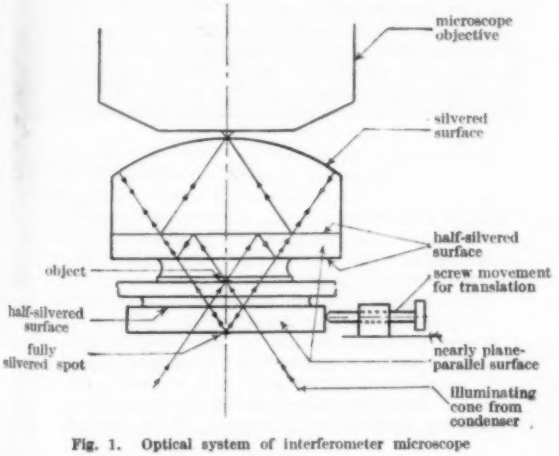
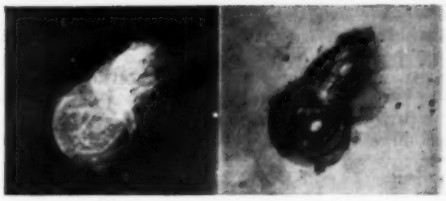


Fig. 1. Optical system of interferometer microscope



(*a*) (*b*)

Fig. 2. Epithelial cells (*a*) with effective 'dark-ground' contrast; (*b*) same cells with different phase adjustment, giving 'bright-ground' contrast. × 225

A second plate is placed above the object. Both surfaces of this plate are half-silvered. Part of the beam which illuminates the object suffers two internal reflexions, whereas part of the beam which was twice reflected in the lower plate traverses the upper plate directly. If the two plates are of identical thickness and correctly aligned, the two emerging beams are coincident. These two beams are collected by an objective system of a type previously described[1]. The two superimposed images thus presented to the observer contain, respectively, the image of the light source and the image of the light source with the object superimposed, and interference will take place between them.

If the two plates are made with a very slight wedge angle, the phase difference between the two interfering fields can be very conveniently varied by translating one plate laterally by a screw movement. The necessary additions to a microscope with a rotating and centring stage are quite small, as the screw movement referred to above can be provided by one of the centring screws.

Figs. 2*a* and *b* are two photographs of a pair of epithelial cells with different values of phase difference between the interfering fields. The apparent 'relief' effect in Fig. 2*b* is due to the fact that the two fields made a small angle with each other and so the phase difference varies across the object; objective N.A. 0·75, condenser N.A. 0·5.

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Mechanism of the Formation of Pearlite in Steels

For the sake of simplicity, we shall consider the case of an eutectoid steel; if the steel is cooled slowly from the austenitic region, a well-known pearlite structure is formed in crossing the A_1 line, that is, 726°, and remains as such down to room temperature. During heating, just the reverse change will take place. The mechanism of formation of this remarkable structure, referred to as 'pearlitic', is not yet known, at least so far as I know. My view regarding the mechanism of formation of the lamellar structure is as follows.

According to my theory[1], the mechanism of the A_1-transformation consists of the following two steps: A_1 transformation $\equiv$ austenite $\rightleftarrows$ α-iron dissolving carbon $\rightleftarrows$ pearlite; hence, if the steel is cooled down to the A_1 point, the first step of the change, austenite → α-iron dissolving carbon begins to take place, with several nuclei as centres. The change is also accompanied by a volume change of the order of magnitude $\frac{\delta v}{v} = 8 \times 10^{-3}$, so the grains undergo a great pressure from their surroundings. This pressure[2] may amount to

$$p = \tfrac{1}{2} K \frac{\delta v}{v} = 30 \ Kg/\text{mm.}^2,$$

K being the bulk modulus of the steel. By this pressure, slip bands are formed in the interior of each grain, then carbon atoms in unstable conditions in an α-lattice find their way out of the iron lattice and assemble in very thin cavities in the slip bands, resulting in the formation of pearlitic structure; thus the second change, α-iron dissolving carbon → pearlite, is completed, resulting in lamellar pearlite.

According to the above view, the distribution and the form of cementite flakes depend principally on those of slip planes. It is also easily realized that the directions of pearlite flakes in each grain are parallel to each other, but vary from grain to grain. The important fact that the thickness of cementite flakes is nearly constant can be explained by the equal concentration of carbon in both sides of each slip band.

The above simple explanation, which is based on the mechanism of the A_1-transformation, and assumes the boundaries of slip bands to be the seat of precipitation of cementite particles, agrees very satisfactorily with observed facts.

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Structure of Tempered Martensite

INVESTIGATIONS are being carried out on tempered martensite in samples which have been previously subjected to very low temperature treatment. Two plain carbon steels were chosen containing 0·89 per cent and 1·2 per cent carbon respectively.

A detailed account concerning the preparation of the specimens has been given in a previous communication[1]. After quenching from 780° C. and 930° C. in brine, the rods were immersed in liquid air for one hour, liquid nitrogen for 30 min. and finally in a liquid helium bath at about 1·5° K. for approximately six hours. After liquid-helium treatment, the rods were tempered for 48 hr. at 100° C. in boiling water. Immediately after each treatment, X-ray diffraction photographs were taken both with 9-cm. and 19-cm. Debye–Scherrer cameras, using cobalt radiation and an iron filter.

After helium treatment but before the tempering process, both austenite and martensite lines were clearly visible; the lines M'_4 (002) and M'_6 (112), using the designations adopted by Lipson and Parker[2], were weaker in the case of the sample with 0·89 per cent of carbon. The question arises what effect liquid-helium temperature has on austenite and martensite. Harder and Dowdell[3] pointed out that the decomposition of austenite into martensite does not go to completion in liquid oxygen. On the basis of my investigations, the validity of the above statement can be extended to the region of very low temperature, namely, the liquid-helium bath. This opinion is in full accordance with Orowan's theory[4] concerning martensite transformation.

After tempering, the structure does not give sharp X-ray diffraction spectra, and in all photographs it was particularly noticeable that the high-angle lines are either missing or too faint. The tetragonal structure which is characteristic of martensite starts to decompose at a temperature as low as 100° C. In the case of 0·89 per cent carbon, the decomposition is quicker than in 1·2 per cent carbon.

To determine the lattice parameters, special care was taken to obtain the real centre of the intensively broadened and diffuse lines; the exact positions of the peaks were calculated according to the method recently described by Stokes[5], the ferrite lines (110), (200), (211), (220), (310) being used as 'standard' lines; pure iron powder of known lattice parameters mixed with Canada balsam partly covered the rods. X-ray diffraction photographs of such specimens give, besides the martensite lines, additional very sharp ferrite lines. The results of the evaluation of sin θ for martensite and ferrite lines are listed in Table 1.

Table 1. 19-cm. Camera film. Specimens tempered after quenching from 930° C. and immersion in liquefied gases, including liquid helium.

	Sin θ		
h k l	Electrolytic iron	0·89 per cent of carbon	1·20 per cent of carbon
110	0·44239	0·44520	0·44486
200	0·62634	0·62769	0·62666
211	0·76641	0·76641	0·76641
220	0·88489	0·88358	0·88340
310	0·98694 for a_1 0·98906 „ a_2	faint and diffuse	

A striking feature of the tables is the great similarity of the tempered martensite and ferrite lines. The martensite structure is not stable. On the basis of this similarity, the tempered martensite can be regarded as a ferrite mixed with precipitated cementite. Some years ago, the late Prof. W. Broniewski[6] expressed the opinion that the longer the martensite is subjected to the tempering process, the more it changes over into ferrite mixed with a primary form of precipitated cementite; he strongly objected to the β-martensite hypothesis, and his belief seems to be completely confirmed.

The second striking feature shown by the X-ray diffraction films in the present investigations is the change of distance between the peaks of austenite A_3 (111) and martensite M_3 (110) lines. According to Kurdjumow[7], the changes in the distance between austenite and martensite lines are connected with the process of decomposition.

Table 2 clearly shows that the distance between these lines is affected not only by the carbon content but also to some extent by the influence of low-temperature treatment and the tempering process.

A full account of this work will be published elsewhere. The physically interesting question of reversibility and of the influence of the amount of

Table 2. 9-cm. Camera film

	(i)		(ii)		(iii)		Tempered at 100° C.
	c/a	Distance A_2—M_2	c/a	Distance A_2—M_2	c/a	Distance A_2—M_2	Distance A_2—M_2
0·89 per cent C	1·0409 ± 0·0001	0·80 mm.	1·0407 ± 0·0001	0·73 mm.	1·0402 ± 0·0001	0·65 mm.	0·85 mm.
1·20 per cent C	1·0568 ± 0·0001	1·20 mm.	1·0566 ± 0·0001	1·09 mm.	1·0564 ± 0·0001	1·00 mm.	1·25 mm.

(i) Samples quenched in brine, followed by (ii) immersion in liquid air and nitrogen, and finally by (iii) immersion in liquid helium.

martensite upon the temperature are the next steps in the present investigations. I wish to express my appreciation to Prof. C. W. Dannatt, head of the Department, for his constant interest in this work, and to Drs. G. W. Brindley and H. Lipson for many helpful discussions of theoretical points.

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Laminated Structure in Recrystallized Aluminium

BY electron microscope studies of alumina replicas taken by well-established methods[1] from specimens of recrystallized aluminium we have observed a fine laminated structure (Fig. 1). This has a mean spacing of approximately 600 A., from which variations do not exceed 100 A. The laminations themselves appear to have a nodular structure which is very clear in the example of Fig. 1, although the nodules are not always so clearly resolved. The general direction of the laminations over a wide field is constant; but over small distances (of the order of 15,000 A.) the direction varies two or three degrees from this. This laminated structure differs from those previously observed in metal crystals by Straumanis[2] and Graf[3], which have spacings of the order of 10,000 A.

The laminations have been observed in several samples of aluminium, including 99·99 per cent metal and 98 per cent commercial sheet, in every case after cold working and annealing at 550–600° C. for at least two hours: further annealing up to a total time of 90 hours has no effect. The specimens were electrolytically polished, and laminations were observed both on the polished surface and after etching in Lacombe's hydrofluoric–hydrochloric–nitric acid reagent[4]. This etching, of course, produces etch pits, and these make possible a determination of the orientation of the laminations the general direction of which may be interpreted as [100].

In Fig. 2 a cubic etch pit, part of which shows at the top right-hand corner, has its base practically parallel to the replica and its sides normal to it: it follows that if the pit is of {100} form, the plane of the replica is also nearly (100), and in this particular case the structure is in the form of whorls resulting from the intersection of a plane and the undulating laminations to which it is almost parallel.

The behaviour of the laminations at the boundary between two grains is particularly interesting (Fig. 3); it is apparent that any interruption in the normal crystal structure at the boundary cannot exceed a width of about 150 A. in the very pure metal.

Note added in proof. This phenomenon appears to be the same as one mentioned by A. F. Brown in the last paragraph of his letter dated May 2, which appears in *Nature* of June 18, page 961.

Fig. 1. 99·99 per cent aluminium, electrolytically polished but unetched (× 9,500); Fig. 2, etched specimen of 98 per cent aluminium showing a boundary between two grains, the surface of one lying almost in the plane of the laminations (×8,500); Fig. 3, etched specimen of 99·99 per cent aluminium showing the sharp boundary between two grains (× 6,000)

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Product of Interaction between Influenza Virus Enzyme and Ovomucin

THE presence of an enzyme at the surface of influenza virus was first suggested by Hirst[1]. Burnet and co-workers[2] have presented much evidence to substantiate Hirst's assumption, especially by their discovery that the ability of certain mucoproteins to act as competitive inhibitors for hæmagglutination by heated influenza B virus[3] is lost after pre-treatment of the mucoids with active virus. Serum mucoprotein, ovarian cyst mucoid, blood group substances *A* and *O*, gonadotrophic hormone proved to be inhibitors of hæmagglutination by heated virus and substrates for active virus.

Recently, ovomucin was shown to be a powerful virus hæmagglutinin inhibitor[4]. Ovomucin is a protein fraction consisting of a virus hæmagglutinin inhibitor, a non-inhibitory component[5] and lysozyme[6]; the inhibitor constitutes about 6–8 per cent of the total fraction, as was demonstrated by selective and irreversible adsorption of the inhibitor on to virus-coated erythrocytes[4]. Whereas most of the lysozyme can be crystallized out at its isoelectric point directly from an ovomucin dispersion, further purification of the inhibitory substance meets with great difficulties which have not yet been overcome. The work described below was carried out to characterize the product of interaction between influenza virus enzyme and its substrate in the ovomucin fraction.

The experiments were performed with the Melbourne strain of influenza A virus on the basis of the finding by Stone[7] that this strain is highly effective in reducing the inhibitory titre of ovomucin.

Assay. Virus and ovomucin (about 150 mgm. N), both prepared and purified as previously described[4], were allowed to interact at 38° C. until the inhibitory titre of the ovomucin was reduced by more than 95 per cent; the reaction mixture was then dialysed against glass-distilled water.

Control. The same amount of ovomucin was mixed with heat-inactivated virus and subjected to the same procedures as the assay.

Analysis of the dialysate from the assay, after concentration *in vacuo*, revealed the presence of water-soluble nitrogenous material with appreciable reducing power. After alkaline hydrolysis, the material reacted with *p*-dimethyl-aminobenzaldehyde to give a purple colour identical with, but much more stable than, that produced by an authentic specimen of N-acetyl D-glucosamine (oxazole reaction)[8]. The alkaline hydrolysis of the split product followed the course of a first-order reaction (cf. graph). Optimal conditions for maximum colour intensity in the oxazole reaction and for maximum reducing power were found to be 12 min. heating at 100° C. with 0·1 *N* sodium carbonate. Even prolonged heating (30 min.) under these conditions did not result in a diminished colour intensity in the oxazole reaction, or in a significant loss of reducing power, as occurred when a sample of N-acetyl D-glucosamine was treated similarly for more than 10 min. Spectroscopic examination (Hartridge spectrometer) disclosed identity of the bands (prominent band at 587 mμ and a less intense one at 544 mμ) given by the colouring matter in the oxazole reaction with N-acetyl D-glucosamine and with the split product respectively as reactant. N-acetyl D-glucosamine, heated with 1 *N* hydrochloric acid for 1 hr. at 100° C., was found to lose about 95 per cent of its acetyl group. When the split product was treated under similar conditions, the oxazole reaction almost disappeared. Condensation of the acid-hydrolysed split product with acetyl acetone in alkaline solution, followed by addition of *p*-dimethyl-aminobenzaldehyde, gave rise to a red colour of a shade very closely matching that of a D-glucosamine standard[8]. During acid hydrolysis (as above) of the split product, a considerable amount of humin substance was formed, coincident with the loss of more than half of the reducing power (Hagedorn–Jensen) and of the amino-sugar, determined as glucosamine.

The Molisch test was strongly positive in the assay, negative in the control. The reducing power of the split product after complete alkaline hydrolysis exceeded considerably the value to be expected from N-acetyl D-glucosamine, which has 88 per cent of the reducing power of an equimolar quantity of glucose in the Hagedorn–Jensen method (cf. table). These results would suggest the presence of a non-amino-sugar in the split product. Experiments are in progress to identify the non-amino-sugar component by paper partition chromatography.

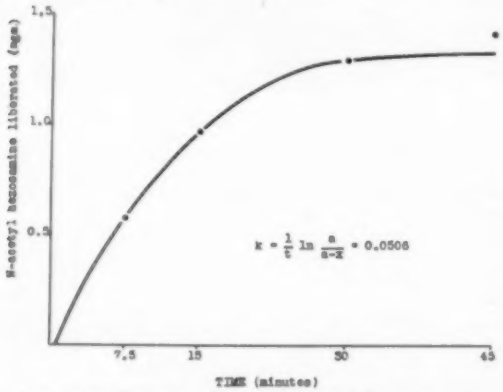
Analysis of the alkaline hydrolysate of the split product*

N-acetyl-hexosamine (mgm.)	Reducing power to be expected from previous column (mgm.)	Total reducing power found (as glucose) (mgm.)	Total N (mgm.)	Amino-sugar N / Total N (%)
1·38	0·99	1·66	0·34	25·7
1·50	1·07	1·79	0·41	23·2
1·42	1·02	1·70	0·40	22·5

* All figures refer to mgm. per assay; the figures for total reducing power and for total nitrogen are corrected for the small values of the controls; no N-acetyl hexosamine was found in the controls.

More nitrogen was present in the split product than could be accounted for by the amino-sugar (cf. table). Paper chromatography (solvent: phenol/ammonia; reagent: ninhydrin) revealed after alkaline hydrolysis (1 *N* sodium hydroxide; 24 hr., 100° C.) ninhydrin-reacting spots which were absent before hydrolysis and in samples of the control similarly treated. The component amino-acids await identification.

Action of the receptor-destroying enzyme of *V. cholerae*[9], highly purified by ammonium sulphate fractionation, on ovomucin and H substance, prepared from ovarian cysts and kindly supplied by Dr. W. T. J. Morgan, of the Lister Institute, respectively yielded also hexosamine and reducing groups.



Rate of liberation of N-acetyl hexosamine from the split product by heating at 100° C. with 0·025 *N* sodium carbonate

No dialysable split product was detectable when ovomucin, the inhibitory portion of which had been removed by selective adsorption, was acted upon by virus[5].

The experimental data would indicate that the interaction between virus enzyme and the virus haemagglutinin inhibitory component of ovomucin results in the liberation of a carbohydrate-peptide complex. The carbohydrate moiety of the split product has been characterized as an oligosaccharide containing one or more N-acyl (acetyl) hexosamine residues linked by an alkali-labile glycosidic linkage to a non-amino-sugar. The alkali stability of the N-acetyl hexosamine component of the split product and the great stability of the colour which it gives in the oxazole reaction may best be explained by the assumption that the amino-acids are attached to the amino-sugar rather than to the non-amino-sugar. Since the reducing power of the substituted N-acetyl hexosamine is not known, the molecular ratio of the amino- to the non-amino-sugar cannot be evaluated. The presence of an N-acetyl hexosaminide, hydrolysable by alkali, has been found characteristic of all substrates for the viral enzyme tested so far.

No similar enzyme could be detected in normal allantoic fluid from the developing egg or in the chorio-allantoic membrane, indicating that the enzyme is an integral part of the virus particle rather than an incidental catalyst derived from the enzymatic equipment of the host cell.

We are greatly indebted to Prof. V. M. Trikojus and Mr. F. J. R. Hird, of the University of Melbourne, for their helpful advice and co-operation.

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Action of Suramin and 'Antrycide' on Enzymes

Recently[1,2] we described the inhibitory effect of the trypanocidal drug, suramin, on certain enzymes. Hexokinase, urease, yeast decarboxylase, succinic dehydrogenase and trypsin are all strongly inhibited by concentrations of suramin similar to those maintained in the blood plasma of man and other animals for at least several hours after the intravenous injection of a normal dose (1–2 gm.) of the drug. For example, $M/10{,}000$ and $M/20{,}000$ suramin give respectively 100 and 75 per cent inhibition of the action of hexokinase, and, with low substrate concentrations, $M/10{,}000$ suramin inhibits the hydrolysis of casein by trypsin to the extent of 56 per cent.

Further investigations have fully confirmed our suggestion that enzyme inhibition by suramin is relatively specific; a few are inhibited at *p*H 7–8, some others are inhibited only on the acid side of the isoelectric point of the enzyme, and many enzymes are unaffected by the drug through the whole range of *p*H over which they act. No evidence is yet available to show whether or not enzyme inhibition plays any part in the action of suramin on trypanosomes, but the possibility of such an effect, with a consequent disturbance of carbohydrate and/or protein metabolism in the trypanosome, cannot be excluded.

Following the recent discovery[3] of 'Antrycide', the new trypanocidal drug now being used in Africa for the large-scale cure and prevention of trypanosome infections in cattle, we decided to study the action of this compound on some of the enzymes which are inhibited by suramin. These two trypanocides have very different structures; in fact, they have little in common from the chemical point of view; but we thought it possible that they might act in a similar way on some metabolic enzymes. By the courtesy of Messrs. Imperial Chemical Industries, Ltd., we were able to have a supply of 'Antrycide' before it became generally available.

Our experiments have shown that 'Antrycide', in concentrations as high as $M/500$, has no inhibitory effect on urease, succinic dehydrogenase and the system of yeast juice enzymes required for the fermentation of glucose; and the hydrolysis of casein by trypsin is not significantly inhibited by $M/2{,}400$ 'Antrycide' (higher concentrations of the drug precipitate the substrate). All these enzymes or enzyme systems are strongly inhibited by suramin. Some of these enzymes are actually mildly stimulated by high concentrations of 'Antrycide'.

These results do not, of course, show that 'Antrycide' and suramin exert their trypanocidal actions by different mechanisms. They would, however, furnish proof of such a difference if it should be eventually established that the inhibition of glucose-metabolizing and/or proteolytic enzymes is an essential feature of the trypanocidal action of suramin.

We are indebted to the Medical Research Council for a grant towards the expenses of this work, and to Mr. S. Ellingworth, of Messrs. Imperial Chemical Industries, Ltd., for having arranged for us to have a supply of 'Antrycide'.

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Difference in Composition of the Allantoic Fluids of Eggs Infected with Virus and that of Normal Eggs

Early in the course of an investigation by the method of electrophoresis of Polson[1] of the allantoic cavity fluid collected from developing chick embryos infected with different viruses by various routes, it was apparent that there is a marked difference between the fluid obtained from infected eggs and that from uninfected fertile eggs incubated in forced-draught incubators under identical conditions of temperature, humidity and time.

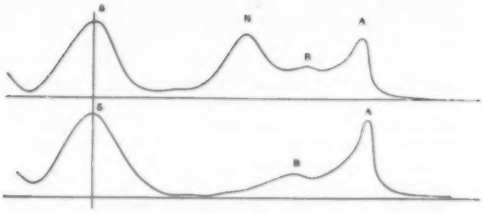

Fig. 1. Ascending electrophoresis curve of allantoic fluid of eggs infected with lumpy skin disease (above) and corresponding curve of normal allantoic fluid (below)

The pooled fluid from a number of eggs in each group was concentrated tenfold by evaporation in 'Cellophane' bags at room temperature (approximately 85° F.) prior to dialysis for forty-eight hours against 0·0133 *M* phosphate buffer containing 0·28 per cent sodium chloride, *p*H 7·9.

In Figs. 1 and 2 the upper curves depict the electrophoresis diagrams obtained with fluid from eggs infected with lumpy skin disease virus and blue tongue virus respectively, while the lower curves represent similar diagrams from non-infected eggs.

Consideration of the diagrams makes it clear that in the fluid from the infected eggs there is a considerable increase in the protein content. At this stage of the analysis it is not claimed that the additional component is the virus; but it has been determined by the suitable adaptation of the sampling technique of Polson[1] and Polson, Joubert and Haig[2] that the virus is associated with peak *N* in the case of lumpy skin disease and N_2 in the case of blue tongue.

In electrophoresis experiments with fluid from eggs infected with canine distemper (Haig[3]) by the choric-allantoic membrane route, no increase in protein content could be determined. Biological tests with the fluid at the time of harvesting failed to reveal the presence of any virus, whereas in the case of lumpy skin disease and blue tongue, virus is present in the allantoic fluid in fairly high concentration.

The presence of the protein in the allantoic fluid can be determined by means other than electrophoresis. For example, a heavy precipitate is formed when a few drops of infected fluid are added to trichloracetic acid, whereas no precipitation is produced with normal fluid. Also the refractive index of infected fluid differs markedly from that of normal fluid.

It is concluded that, as a result of propagation of certain viruses in fertile eggs, there is a marked increase in protein in the allantoic fluid. Electrophoretically, the protein components are found in the *N* position. It is suggested that the finding may be of considerable value in following the multiplication of viruses without resorting to the biological animal test, more particularly if a quantitative relationship between the protein and the virus is established.

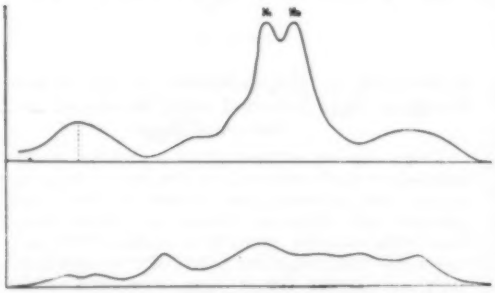

Fig. 2. Ascending electrophoresis curve of allantoic fluid of eggs infected with blue tongue virus (above) and corresponding curve of normal allantoic fluid (below)

Very recently, Atlas and Hottle[4] have noted similar chemical changes in the allantoic fluid of eggs infected with cold virus when compared with that of normal fertile eggs that were incubated. These authors were able to correlate the titre of the infected fluids with the intensity of its tryptophane-perchloric acid reaction.

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Nutrition of a Strain of Brewer's Yeast Requiring *p*-Aminobenzoic Acid

ONE of us recently reported[1] strains of brewer's yeast requiring *p*-aminobenzoic acid for growth in a synthetic glucose – mineral salt medium. Two additional strains similarly requiring *p*-aminobenzoic acid have now been isolated from a brewery pitching yeast.

If the medium is modified by the inclusion of vitamin-free casein hydrolysate, the requirement for *p*-aminobenzoic acid can be met by the addition in its stead of a relatively large amount of adenine (of the order of 20 μgm. per ml. of medium). Guanine, xanthine, uracil and thymine will not replace adenine, which itself is inactive in the absence of amino-acids. Investigations with single amino-acids using 'Yeast 47' as test organism[1] have shown that methionine (the DL-compound was tested) is the necessary complement to adenine in promoting growth, and that this effect is greatly enhanced by L-histidine.

The facts indicate that *p*-aminobenzoic acid is concerned in the synthesis of adenine and methionine and also connected in some way with that of histidine. In this connexion, Shive and Roberts[2] conclude, from inhibition experiments with analogues of *p*-aminobenzoic acid on *E. coli*, that the vitamin functions in the synthesis of purine bases and methionine, whereas Hall[3] has shown that histidine may replace folic acid as a growth factor for *Streptococcus lactis* R. The situation with *Lactobacillus arabinosus* is more complex, this organism requiring both thymine and a purine in an amino-acid medium before being able to dispense with *p*-aminobenzoic acid[4].

Yeast 47 permits a more direct approach to the problem of the relationship between *p*-aminobenzoic acid, the purines and amino-acids than is possible in inhibition studies, and its relatively simple nutritional requirements may prove an advantage over organisms exacting towards amino-acids.

In view of the fact that other substances can function in lieu of *p*-aminobenzoic acid, the validity

of assays of the vitamin involving micro-organisms is questionable.

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Carbon Dioxide Narcosis

Carbon dioxide has been used as a narcotic for invertebrate animals for many years; but the nature of its action is not yet understood. It has recently come into prominence in the discovery of strains of *Drosophila* sensitive and resistant to carbon dioxide (reviewed by l'Héritier[1]). In using carbon dioxide as a means of temporarily immobilizing aquatic invertebrates for extraction of blood samples, we have been struck by some remarkable interspecific differences in sensitivity and have been led to investigate the problem.

We have so far experimented on the insect larvæ *Sialis lutaria*, *Corethra plumicornis*, *Aeschna cyanea* and *Perlodes mortoni*, and on the freshwater Crustacea *Asellus aquaticus* and *Gammarus pulex*. All these species are immobilized in one or two minutes when pure carbon dioxide is blown through about 50 c.c. of water. *Gammarus* will recover if treatment is no longer than about 15 minutes, but is killed by exposure of an hour to carbon dioxide. *Asellus*, *Aeschna* and *Perlodes* are all less affected, but do not recover if treatment is longer than about five hours. On the other hand, we have kept *Sialis* and *Corethra* for more than nine days in sealed vessels of pure carbon dioxide, from which they will recover within an hour when transferred to aerated water.

Neither narcotic nor toxic effect is due to lack of oxygen. A mixture of equal parts oxygen and carbon dioxide will immobilize these animals as rapidly as pure carbon dioxide which has been deoxygenated by passing through acid chromous chloride, and *Gammarus* is killed, though rather less rapidly. The differential effect was also well shown by a mixture of 25 per cent carbon dioxide, 20 per cent oxygen and 55 per cent nitrogen. This had no visible effect whatever on *Sialis*, and *Corethra* and *Asellus* became slightly less active only after several hours; but *Gammarus* was rapidly narcotized and did not recover if exposed to it for more than about an hour.

It is interesting to note that during several days of narcosis in pure carbon dioxide, the blood chloride of *Sialis* and *Corethra* is maintained at the normal level. We have reason to suppose that salt retention in these larvæ is mainly a matter of extremely low permeability, whereas with *Gammarus* salt is lost through the body surface and is continuously replenished by active absorption from the medium (to be published elsewhere). The toxicity of carbon dioxide to *Gammarus* may therefore be due to its effect on the salt-absorbing mechanism. But this requires further investigation and extension to other species.

The penetration of carbon dioxide can be followed by its effect on the *p*H of the blood, and by means of micro-glass capillary electrodes it has been possible to measure this without exposing the blood to the atmosphere. We have found that, in the first place, under normal conditions in equilibrium with air, there are considerable individual and some interspecific differences in blood *p*H: *Sialis*, 7·2–7·5; *Gammarus*, 7·6–8·0; *Asellus*, 7·3–7·8. Measurements were then made after half an hour in pure carbon dioxide, when the *p*H-levels reached were: *Sialis*, 6·0–6·4, *Gammarus*, 6·4–6·8; *Asellus*, 6·5–6·8. These figures suggest that the blood of *Gammarus* is more highly buffered than that of *Sialis*, and that the toxic effect upon the former is not primarily due to low blood *p*H. As much can be said of the narcotic effect, since during the first half-hour in 25 per cent carbon dioxide the blood *p*H of *Gammarus* and *Asellus* both drop to about the same level (7·1–7·2); though, as stated above, this treatment narcotizes and eventually kills *Gammarus*, but fails even to narcotize *Asellus*.

It seems, therefore, that narcosis is due to carbon dioxide as such rather than to the consequent drop in blood *p*H, though we intend to confirm this by reducing the blood *p*H by acids other than carbonic. There is no evidence that the interspecific differences are due to differences in permeability to carbon dioxide, or in the constitution (for example, degree of buffering) of the blood. We hope to investigate whether narcosis is localized at any particular point in the neuro-muscular system, and whether it can be blocked by any other conditions. From this we may find some clue concerning the nature of the effect.

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Cultivation of Foot-and-Mouth Disease Virus in Explanted Epithelial Tissue of the Bovine Rumen

For the preparation of vaccine against foot-and-mouth disease a source of the causative agent is needed. This source can be the living susceptible animal; or it can be the artificially cultivated virus, provided that a sufficient quantity of this agent can be produced.

The first to grow foot-and-mouth disease virus were Maitland and Maitland[1] and Hecke[2]. It was cultured by these authors on embryonic guinea pig tissue, but did not show usable antigenicity in bovines. Frenkel and van Waveren[3] successfully grew the first foot-and-mouth disease virus that was fully pathogenic and antigenic for the bovine. They used as culture tissue the skin of bovine, ovine and porcine embryos. With this virus active vaccine against foot-and-mouth disease can be prepared. However, embryos of these animals cannot be obtained so regularly as to make it possible to build up a sufficient supply for large-scale vaccination.

In 1946 Frenkel[4] found a method for growing foot-and-mouth disease virus in explanted epithelial tissue collected from tongues of slaughtered normal bovines, and established with this method the possibility of growing the virus regularly in the desired quantities. Moreover, this procedure was adapted to large-scale production, as stainless steel containers up to 60 litres capacity could be used.

Besides the bovine tongue epithelium, the mucous membrane of the rumen is very susceptible to this virus. This suggested to the first-named author the use of this epithelium for cultivation. We have, therefore, applied a similar method to that used for growing the virus on explanted epithelial bovine tongue tissue.

As a nutrient medium, Baker's solution[4] was used. The mucous membrane was removed from the ruminal wall after it had been washed with warm saline, treated with penicillin and streptomycin in order to prohibit as much as possible growth of micro-organisms present on this tissue, thoroughly minced with scissors and incubated at 37° C. The nutrient medium was aerated with carbogen (95 per cent oxygen and 5 per cent carbon dioxide) to secure sufficient respiration of the tissue.

Not all the various types of epithelial tissue of the rumen are suitable for use. It seems, according to what is observed in the circumstances of the spontaneous disease, that only the smooth part of the ruminal mucosa (pillars) show lesions. This tissue should be used for cultivation of the virus.

In our first attempt, we succeeded in cultivating the virus in twenty-eight successive passages, after which it was inactive for some unexplained reason.

After continuing on the rumen epithelium with virus grown on explanted bovine tongue epithelial tissue, we have propagated it thus far in eight passages, the last two passages showing a titre on bovines of 1 : 279,000 and 1 : 450,000 respectively. This last passage was a large-scale culture (2,000 ml.) in a stainless steel container.

One rumen yields about 75 gm. of epithelial tissue. We obtained with the tissue from two rumens 2 litres of foot and-mouth disease virus of a titre of 1 : 450,000. If we suppose that the average quantity of virus material (vesicles and lymph) of one artificially infected bovine (intradermal infection of the lingual mucosa) is 50 gm. and the average titre of this virus is 1 : 2,000,000, we easily can see that the cultivation in epithelial tissue of one rumen gives us 1 litre with a titre of 1 : 450,000 or about 200 c.c. with a titre of 1 : 2,000,000, which is equal to the yield of four bovine tongues infected during life.

We believe that the use of explanted epithelium from the rumen for the cultivation of foot-and-mouth disease virus to be of high importance. We are convinced that only cultivated foot-and-mouth disease virus can be used in the production of vaccine against this disease. The advantages are: (1) no risk of spreading the disease through mass infection of living animals; (2) great reduction in the costs of virus production; (3) simplification of the method of preparation of the vaccine; and (4) as the result of these advantages, a subsequent lowering of the cost of the vaccine, which should favour a wider usage of the vaccine in the battle against foot-and-mouth disease.

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Triphenyl Tetrazolium Chloride as a Reagent for the Histological Demonstration of Subcutaneous Fat

Subcutaneous fat at the site of injection is stained specifically in five to ten minutes when 0·5 ml. of a 1 per cent aqueous solution of triphenyl tetrazolium chloride is injected into mice. Neutral fat in the deeper layers is stained a bright orange-red, while the secretions of the sebaceous gland cells are stained a brick-red colour.

Similar results are obtained when fresh unfixed strips of skin are immersed in the aqueous solution. The staining reaction is inhibited by most of the common histological fixatives; but these may be used subsequent to the development of colour in the tissues, without deleterious effect.

A variety of contrast stains may be injected in admixture with the triphenyl tetrazolium chloride solution so as to produce simultaneous staining of the various tissue elements. Good results were obtained with solutions containing Janus Green B or Brilliant Cresyl Blue with triphenyl tetrazolium chloride, each at a concentration of 0·5 per cent.

The stained tissues, after removal of hair, may be transferred to any fixative which does not contain fat solvents, and afterwards embedded in gelatine prior to sectioning. The gelatine blocks containing the stained material may be stored for months in 5 per cent formaldehyde solution without loss of colour.

Other mammalian tissues containing deposits of fat, for example, mesentery and lactating mammary gland, stain rapidly and intensely on immersion in aqueous solutions of triphenyl tetrazolium chloride. Particularly intense staining of fatty deposits in the liver of a cat, which had been kept in the laboratory, was observed after immersion in a 1 per cent solution for 1 hour.

When an alcoholic extract of the stained tissues is shaken with an equal volume of arachis oil or animal fat, the red colour passes rapidly into the oil phase. This ready solubility in fats suggests a probable explanation of the staining reaction in fresh tissues, namely, reduction of the triphenyl tetrazolium chloride with precipitation of formazan and re-solution of the formazan in the fatty deposits.

Triphenyl tetrazolium chloride is extremely toxic when injected intravenously into mice, 0·5 mgm. being sufficient to kill instantaneously.

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Brightness and Saturation of Colours in Red-Green Defectives

For theories of colour vision it is important to consider the relationships between the saturation and photopic brightness-levels of certain colours for anomalous and red-green blind subjects.

In a recent series of experiments[1], 23 protanopes, 33 deuteranopes and 31 green anomalous subjects were given tests of saturation of red, green and yellow, and of the photopic brightness-levels of these colours, in a colorimeter which used the Ilford

spectrum colour filters, which are almost monochromatic. Correlations were calculated by the product-moment formula between the variations of saturation and of brightness-level for red among protanopes, and for green among deuteranopes and green anomalous subjects. Correlations between red and green, red and yellow, and green and yellow were also calculated for all three groups. These correlations are shown in the accompanying table.

Number	Subjects	Tests	r
23	Protanopes	R and G saturation	+ 0·652*
		R and Y saturation	− 0·228
		G and Y saturation	− 0·002
		R and its brightness	+ 0·182
33	Deuteranopes	R and G saturation	+ 0·458*
		R and Y saturation	+ 0·167
		G and Y saturation	+ 0·094
		G and its brightness	+ 0·276
31	G Anomalous	R and G saturation	− 0·589*
		R and Y saturation	− 0·034
		G and Y saturation	+ 0·077
		G and its brightness	+ 0·143

* Significant on the 0·01 level.

The correlations between saturations and brightness-levels are not significant even on a lenient level, though all are positive. They give no evidence that the degrees of losses of saturation of the hues in question are directly proportional to the brightness-levels of the same hues for these groups of red-green defectives.

It is true that protanopes as a group have the red end of the spectrum extremely darkened in comparison with deuteranopes[3] and green anomalous subjects; but the variations of this loss of brightness are not correlated with the corresponding losses of red saturation. In deuteranopes and green anomalous subjects, among whom green is not darkened relatively to the normal, though it is greatly desaturated, there is still no relation between this loss of saturation and the corresponding variations of brightness-level.

These facts create difficulties for the Young–Helmholtz theory, or any three-colour theory on which losses of brightness and of saturation should be perfectly correlated. Other writers[3,4] have attempted to meet these difficulties. The facts observed are in accordance with the factorial analysis of colour vision and brightness variations among normal persons[5], and with Granit's[6] data.

Further difficulties for the Young–Helmholtz theory are created by the positive correlations between losses of red and of green saturation, which are significant on the 0·01-level, and which confirm the view that protanopes and deuteranopes are not to be regarded as 'red' and 'green' blind, but both as 'red-green' blind. This has been pointed out many times during the past half-century[7,8]. The difference between the red-green blind and the green anomalous subjects is well brought out by the fact that the correlation between red and green saturations among them is negative and significant, as it is among normal subjects[5].

On the Young–Helmholtz theory it is equally difficult to understand why no correlations are found between either red or green and yellow saturations, for any of the groups of major defectives. This again accords with what has been found for normal subjects[5]. Although according to this theory yellow is produced by the combined effect of red and green sensations, its saturation varies independently of the losses of red and green among red-green blind, anomalous and normal subjects. This is strong evidence that it is an independent sensation.

Facts which the three-colour theory is apparently incapable of explaining will be found to accord readily with expectations based on a modified form of Hering's theory, such as that of Houstoun[9], or a variant of it, on which there would be two bipolar systems of hue determination and one system for photopic brightness.

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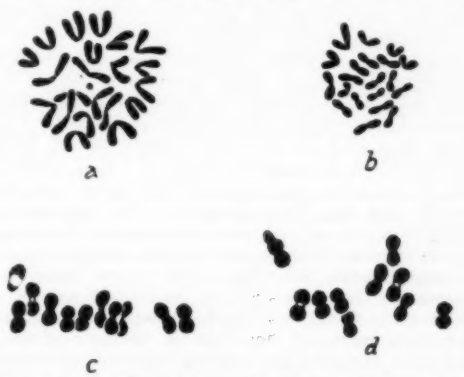
Evolutionary Changes in the Sex Chromosomes of Coleoptera

Two closely related species of buprestids, at the present time referred to the species *Agrilus anxius* Gory, have been shown by a colleague, G. W. Barter (unpublished), to be separable on morphological grounds. One is restricted to birch, the other to poplar.

Males and females from birch have 22 chromosomes, those from poplar only 20. Males from birch possess 21 relatively large mediocentric chromosomes of approximately equal size and a minute, spherical chromosome (Fig. *a*)—this, not being present in the female, is the *y*-chromosome (the use of the small letter indicating its small size). Males from poplar have 19 chromosomes of the former type and one larger submedian chromosome (Fig. *b*)—this, being present twice in the female, is the *X*-chromosome. Hence, the *Y*-chromosome in this species is large (and consequently the capital letter is used). Males of both species exhibit positive heteropycnosis during the resting stages and the early prophase of meiosis.



a and *b*, Spermatogonial mitoses; *c* and *d*, metaphase I, in male forms from birch and poplar respectively. Squash preparations: Feulgen Light Green. *c*. 3,300 ×

the stainable element being larger in the birch species. From early first metaphase on through anaphase, the positive heteropycnosis of the sex chromosomes becomes negative.

In both species, association between the sex chromosomes at metaphase I is by two terminal chiasmata. The *Xy* bivalent of males from birch resembles a parachute, is late in congression, and, as stated, is negatively heteropycnotic (Fig. *c*). The *XY* bivalent of males from poplar is likewise heteromorphic but in a different way; it is co-ordinated with the autosomes, and only part of it, that constituting the proximal inequality in one chromosome, is negatively heteropycnotic (Fig. *d*). First anaphase is invariably reductional for the sex chromosomes in both species, and spermatids of two types, with and without a heteropycnotic body, are formed in equal numbers.

A numerical difference could result from either chromosome loss or chromosome 'fusion'. A consideration of the relative distribution of heterochromatin in the two, however, shows that both phenomena were concerned in the change: the *y* has been lost, and part of the original *X* excluding the centromere was intercalated near the centromere in one arm of an autosome. The increase in size of the neo-*X* compared with that of the old *X* in specimens from birch, and the decrease in size of the heteropycnotic body in males from poplar, show that only part of the old *X* has persisted in the origin of the neo-*X*. The unaltered homologue of the autosome involved became, at the moment of the translocation, the neo-*Y*, and, being autosomal in origin, it and its homologous parts in the neo-*X* retain their euchromatic staining reaction. Males and females from birch can, therefore, be symbolized as $20A + Xy$ and $20A + 2X$; males and females from poplar as $18A + \overline{AX}A$ and $18A + 2\overline{AX}$ (the bar over the letters indicating fusion by translocation).

The observation that anaphase is always reductional for the sex pair is in agreement with this interpretation. The pairing and differential segments are respectively distal and proximal in both complexes. In the *Xy* system the pairing segments are short and the differential segments correspondingly long as determined by the minute length of the *y*-arms. In the neo-*XY* system the pairing segments occupy the whole of each of the *Y* arms and all of one arm and the long distal part of the other arm of the neo-*X*. The differential segment is thus restricted to a proximal position in one arm of the neo-*X* and has no counterpart in the neo-*Y*.

Our evidence points to the occurrence of two causally related events in the evolution of the neo-*XY* from the old *Xy* system; obviously, one must have predated the other. It is highly probable that the birch borer (*AA Xy* or *AA XX*) gave rise by translocation to an intermediate type ($A\ \overline{AX}\ y$), which in turn produced the poplar borer ($\overline{AX}\ A$) by losing the minute and then superfluous *y*. The hypothetical intermediate type, with two chromosomes, the *y* and neo-*Y*, subserving the same function, would certainly be mechanically unstable. There are three considerations that point to the validity of this interpretation. First, one, and perhaps both, of the *X* pairing segments were lost at the time of translocation; secondly, the *y*, being largely if not entirely inert, could be readily dispensed with; and, thirdly, such a mode of origin, involving first translocation, could occur in either sex. The alternative, initial loss of the *y* followed by an independent and fortuitous translocation is quite improbable. In origin, it would, of course, be restricted to the male.

A cytological survey carried out as occasion permitted during the past five years, together with a review of the literature, provides a total of about a hundred species of beetles of which the chromosome complements are known to me. Excluding *Blaps lusitanica* (Hbst.) with a multiple sex chromosome mechanism, ten parthenogenetic species and nineteen with an *XO* system, there remain seventy-six species of which only five have an *XY* system in which the *Y*- approaches the *X*-chromosome in size. It is, therefore, obvious that the form from poplar is the derivative species and the form from birch the primitive one.

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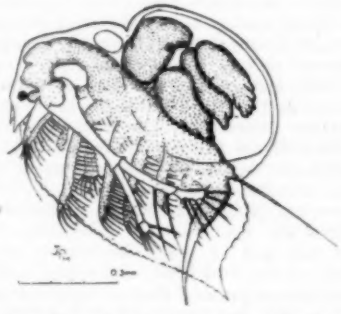
Penilia, a Cladoceran Normally Found off Tropical and Sub-tropical Coasts, Recorded in North Sea Plankton

In October 1947 the Ministry of Agriculture and Fisheries Research Ship *Sir Lancelot* when on a plankton cruise collected many specimens of a cladoceran never before found in the North Sea. They were all from a single station near the Dutch coast at 52° 22′ N., 04° 20′ E.; moreover, all were females, many with young in the brood pouches (see accompanying illustration); no males were seen. The cladoceran remained unidentified until July 1948, when it was referred by the second of us to *Penilia avirostris* Dana.



Dana first described the species in 1849[1] from Rio de Janeiro, together with a second new species, *P. orientalis*, from the Sunda Straits. In 1895 two further species were added, namely, *P. schmackeri* Richard from Hong Kong and *P. pacifica* Krämer from New Zealand. It is now generally agreed that these four names refer to one and the same widely distributed species. It has been found in the coastal waters of all tropical oceans and its distribution extends both north and south into warm temperate regions; also it seems to be well established in the Mediterranean and Black Seas. But its recent occurrence in the North Sea is surprising since the nearest recorded position seems to be in the Mediterranean off the south-east coast of Spain[2]. Mr. F. S. Russell has

kindly informed us that the species has not been recorded off Plymouth.

The species was found again in November 1947 at a station where it had not been present in October; in December no specimens were found. At neither of the two positions were any other unusual animals found. In July 1948 the position of the original record was revisited; but neither at this nor at two further stations at 10-mile intervals in a direction 276° was *P. avirostris* found. The relevant hydrographic and other data are shown in the accompanying table.

Date	Position	Depth (m.)	Surface temp. (° C.)	Salinity	No. *Penilia* per cub. m.
Oct. 4, 1947	52°22′N. 04°20′E.	12—0	16·68	34·99–35·00	225
Nov. 19, 1947	52°09′N. 03°39′E.	22—0	—	34·72–34·78	7·5
July 27, 1948	52°22′N. 04°20′E.	12—0	18·3	—	0

Penilia is one of the three marine genera of Cladocera which is an order of Crustacea the great majority of which inhabit fresh water. It is much more closely related to the freshwater genus *Sida* than to the other marine genera *Podon* and *Evadne*. In the Bay of Naples and other coastal regions of the Mediterranean and Black Seas, swarms of parthenogenetic females appear in the summer and persist until the autumn, when males and sexual females arise and resting eggs are produced before the winter[3]. This habit of producing eggs which persist through the winter to give rise to rapidly reproducing parthenogenetic generations in the summer is a legacy from the freshwater ancestry and may account for the sporadic and rather dramatic appearance of the species in new localities. It was not known in the Bay of Naples until 1922[4]; but as Dr. Dohrn has kindly informed us, it has appeared there regularly and in great abundance every summer since that year.

It is too early to say definitely that the species has failed to establish itself in the North Sea; but that it should succeed in doing so is unlikely since the area is well outside the 18° C. mean annual surface isotherm which, as Calman noted[5], usually limits the species; even the July isotherm for this temperature runs as far south as the Bay of Biscay.

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Morphological Characters of *Myriochele heeri* Malmgren

Myriochele heeri Malmgren is a widely distributed polychæte, particularly in northern seas, where it frequently occurs in large masses of tubes at considerable depths. I recorded its occurrence off the coast of British Columbia in 1930 [1], and it has been confirmed several times since. It was first described by Malmgren in 1867 [2] from Greenland, Spitsbergen, and other northern localities, and his description and figures have since served for its recognition. The figures have been generally copied in text-books.

It may be worth noting that the particulars of the extremities of the body as they are recorded give a correct picture only when they are in the contracted condition, which is usual in preserved material. In extension, the anterior region of the head forms a cylindrical, funnel-like projection deeply notched on the ventral side. A ventral lobe (*lippen-organ*), probably concerned in tube building, as has been shown to be the case with the homologous organ in the nearly allied species *Ammochares fusiformis* (Delle Chiaje) by Watson[3], can be seen at the base of the notch. It is probable, also, that the tubular anterior region of the head corresponds to the elaborately lobed 'branchial' region in the latter species, particularly since a similar collared condition is said to occur anteriorly in its very young forms. The pygidium of *Myriochele heeri* in extension terminates in a low, wide, dorsal lobe and two longer ventral lobes partially joined.

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Jan. 18.

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Life-Cycle of *Puccinia Gladioli* Cast.

Puccinia Gladioli Cast. has hitherto been described as a microcyclic rust, producing only teleutospores on hosts of the genera *Gladiolus* and *Romulea*. However, and in spite of good germination of the teleutospores after a resting period, all attempts to induce infection with them on the natural host gave negative results. On the other hand, frequent field observations showed that the distribution of this rust does not always follow that of *Gladiolus segetum*, its commonest host. These facts pointed to the possibility of this being a heterœcious rust.

A detailed survey of the places where *Puccinia Gladioli* is normally found showed the occurrence of *Aecidium Valerianellæ* Biv. on *Valerianella discoidea* and *V. carinata* more or less closely associated with the infected gladioli. Inoculations made with æcidiospores of this material, on leaves of potted plants of *Gladiolus segetum*, gave rise after ten days to yellow pustules, which later became dark brown and finally black by the development of teleuto-sori.

The heterœcious condition of *Puccinia Gladioli* being demonstrated in 1946, attempts have since been made to determine the host ranges for both stages of the rust. Of the species inoculated with teleutosporic material, the following proved to be susceptible to infection: *Valerianella auricula*, *V. coronata*, *V. dentata*, *V. discoidea*, *V. eriocarpa*, *V. rimosa* and *V. trichocarpa*, producing spermogonia and æcidia; *Valerianella echinata*, *V. olitoria*, *V. truncata*, *Centranthus Calcitrapa*, *C. ruber*, *C. ruber* var. *albus*. *Fedia Cornucopiæ*, *Valeriana officinalis*, *V. Phu* and *V. pyrenaica* proved to be immune to this rust. By keeping some plants bearing single infections under insect-proof conditions, it was further shown that the rust is heterothallic. The extension of infection seems to be controlled either by environmental conditions or the rate of growth of the host: it is systemic during winter and early

spring (February–April), and local during late spring and summer (May–July), as observed in 1948.

As regards the host-range of the teleutosporic stage, inoculations have been made only within the genus *Gladiolus*. *Gladiolus byzantinus*, *G. communis*, *G. illyricus*, *G. imbricatus*, *G. segetum*, *G. tristis*, and *G. undulatus* proved to be congenial to this rust. Some plants, however, or some sources of plants, of *G. communis*, *G. illyricus* and *G. segetum*, have reactions which ranged from the hypersensitive type to moderate resistance (reaction 2+). On the other hand, *Gladiolus brenchleyensis* (only one plant gave reaction 4), *G. hybridus* (all varieties except Heinrich Klauzleuter, of which some plants gave reaction 0 to 2), *G. palustris*, *G. primulinus* and *G. psittacinus*, were immune to this rust.

The above results show that *Puccinia Gladioli* Cast. is an Opsisuredinea, with the gametophytic stage on different species of *Valerianella* and the teleutosporic phase on species of *Gladiolus*. *Aecidium Valerianellæ* Biv. cannot be mistaken by *Aecidium Fedia-olitoriæ* Bals and DeNot, which occur on *Valerianella olitoria*, and which Tranzchel (1935) proved to belong to the cycle of *Puccinia cynodontis* Desm., a rust on *Cynodon Dactylon*.

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Chemical State of Radioactive Phosphorus (^{32}P)

NUCLEAR reactions initiated by heavy nucleons involve the transfer of considerable energy from the incident particle to the target nucleus. The amount of energy carried off by the recoiling nucleus is generally sufficient to break chemical bonds, or in irradiated crystalline substances to move the atom to a new site in the lattice. Little information is available about the chemical form in which these recoil atoms come to rest, but useful surveys of previous work have been given by Libby[1], and by Edwards and Davies[2]. A study of the literature shows that the knowledge of chemical behaviour following high-energy particle bombardments is especially lacking, the well-known Szilard–Chalmers effect having been mainly studied with slow neutrons.

I have recently investigated the chemical form in which phosphorus-32 is produced by the fast-neutron reaction on sulphur-32. Pure dry sodium sulphide and thiourea samples enclosed in an argon atmosphere were irradiated in the low-energy pile at the Atomic Energy Research Establishment, Harwell. Each sample was then opened in an inert atmosphere and treated with air-free water. The radioactivity of the phosphorus-32 was used as a tracer to determine the behaviour of the newly formed phosphorus atoms. Chemical analysis using carriers for active phosphine, active elementary phosphorus and active phosphate demonstrated that nearly all the phosphorus-32 was now present in a form which was carried down with the magnesium ammonium phosphate precipitate. The results indicate that a recoiling phosphorus atom loses one or more electrons and is thus in an oxidized state. In a solid medium this ion is trapped within the lattice as a positive ion, and when released by dissolving the crystal in water it is at once hydrolysed to one of the various oxyphosphorus ions by a mechanism such as, for example,

$$P^+ + 2H_2O \rightarrow H_2PO_2^- + 2H^+.$$

Investigations have also been made into the behaviour of phosphorus-32 formed from sulphur-32 by the irradiation of carbon disulphide and of elementary sulphur, both of which are insoluble in water. In carbon disulphide, about half the active phosphorus behaves as if it were in the elemental form. It is possible that the remainder enters into chemical combination with the target substance, and the formation of phosphorus sulphides seems likely. Sulphur, which after irradiation has to be brought into solution in, say, carbon disulphide before it can be effectively treated with the air-free water, also gives a good yield of elemental phosphorus-32. This may be explained by the release of trapped phosphorus ions by the organic solvent, allowing them to be discharged before they can become hydrolysed.

Govaerts has reported[3] that more than half the phosphorus-32 produced in neutron-irradiated carbon disulphide can be collected on a positively charged electrode, but no chemical evidence for the existence of a negative ion has so far been obtained.

Further work is in progress, and it is hoped that a full account will be published later.

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An Inert Gas Compound

IN clathrate compounds, one molecular component forms an enclosing structure trapping the second component, for which it need have little attraction. From a consideration of their properties it was suggested[1] that such a compound of an inert gas and quinol might be formed by crystallization of a solution containing quinol and saturated with the inert gas at high pressure. Experiments have now been carried out to test this.

0·7 gm. quinol and 60 c.c. benzene were contained in a stainless steel pressure-vessel. Air was removed by pumping, and there were several further pumpings after admission of argon. The pressure of argon, which was spectroscopically pure, was then raised to 20 atmospheres. The temperature of the solution, initially at 30° C., was raised to 87·5° C., and the vessel was allowed to cool at an average rate of 1° C. per 3 hours to 19·2° C.

Since most crystals of quinol give off a certain amount of gas when dissolved in water, the product was examined as follows. It was placed in a bulb connected to a high-vacuum system; the bulb was also connected to a small water reservoir. The water was first degassed, and then frozen to liquid oxygen temperature. The quinol crystals were degassed for half an hour, the ice was allowed to melt and the resulting water transferred to the bulb containing the crystals. There was a large evolution of gas, and when a small quantity of this was examined in a discharge tube, it gave a discharge identical with that obtained from the cylinder argon.

Liberation of the enclosed component on solution of the substance is typical behaviour for the compounds 3 quinol.*M* [2].

An X-ray examination of the crystals showed that they have the β-type structure common to this series of molecular compounds[3].

A detailed crystal structure examination is being made.

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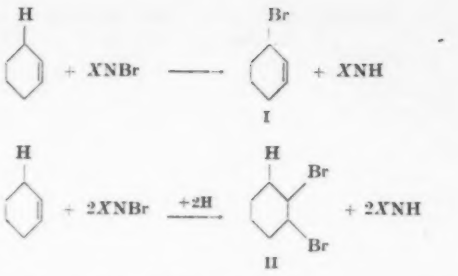
N-Bromosuccinimide as a Reagent for Bromine Addition

It was first shown by Ziegler and co-workers[1] that *N*-bromosuccinimide (*X*NBr) reacts with *cyclo*hexene to give 3-bromo*cyclo*hexene (I) and succinimide. We have found that if the reaction is carried out in chloroform, benzene or petrol solution in the presence of salts such as tetraethylammonium bromide, tetraethylammonium iodide, or triethylamine hydrobromide, 1 : 2-dibromo*cyclo*hexane (II) is formed instead of 3-bromo*cyclo*hexene, in proportions depending on the exact conditions employed. The same effect can be brought about by the addition of small amounts (*c.* 10 mol. per cent based on *N*-bromosuccinimide) of triethylamine, which reacts with part of the *N*-bromosuccinimide to give triethylamine hydrobromide and succinimide.

Analogous observations were made with the reaction between *N*-bromosuccinimide and allylbenzene. In the absence of special catalysts, cinnamyl bromide (III) is formed by substitution in the allyl position, accompanied by rearrangement. In the presence of small amounts of triethylamine, 1-phenyl-2 : 3-dibromopropane (IV) is obtained instead.

Moreover, the salt-catalysed reaction resulting in bromine addition is relatively slow and not accelerated by benzoyl peroxide, whereas the normal reaction resulting in substitution is relatively fast and strongly accelerated by benzoyl peroxide. It will be noted that the addition reaction requires the provision of two extra hydrogen atoms. Since succinimide is always obtained in nearly quantitative yield, whereas the yield of isolatable bromination product is only of the order of 50 per cent, the extra hydrogen atoms must be derived either from the allylic reactant or from the solvent.

These investigations are not yet complete, but we are prompted to record our observations at this stage in view of some recent publications[2] in which it is reported that, even in the absence of special catalysts, the reaction between *N*-bromosuccinimide and *cyclo*hexene affords a very small proportion, and the reaction with *cyclo*butene and methylene*cyclo*butane a large proportion, of the 1 : 2-dibromo derivatives.



I

II

$$Ph\,.\,CH_2\,.\,CH{=}CH_2 + XNBr \longrightarrow Ph\,.\,CH{=}CH\,.\,CH_2Br + XNBr$$

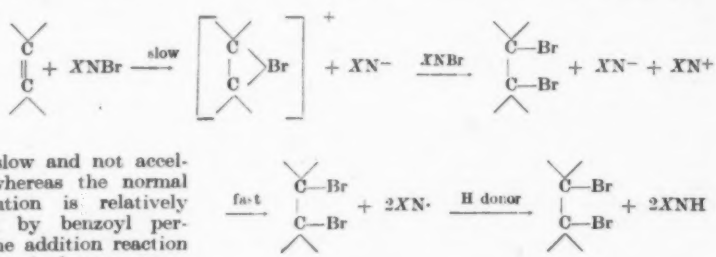
III

$$Ph\,.\,CH_2\,.\,CH{=}CH_2 + 2XNBr \xrightarrow{+2H} Ph\,.\,CH\,.\,CHBr\,.\,CH\,Br + 2XNH$$

IV

Moreover, Buckles[3] has recently shown that another *N*-halogen compound, *N*-bromoacetamide, reacts with ethylenic compounds in chloroform solution to give the dibromo derivatives. The formation of some 1 : 2-dibromo*cyclo*hexane in the reaction between *N*-bromophthalimide and *cyclo*hexene was previously reported by Ziegler and co-workers[1]. The addition reaction can thus be promoted by structural as well as external factors.

It is now generally accepted that allylic substitution with *N*-bromosuccinimide is a free radical chain reaction involving the *homolytic* fission of the N—Br bond[4]. The mechanism of the addition reaction must be different and is of interest. The fact that the addition reaction is catalysed by salts, and, unlike the substitution reaction, not accelerated by peroxides, together with certain other considerations, suggests that it may involve the *heterolytic* fission of the N—Br bond as the primary and rate-determining step; but the formation of succinimide almost certainly involves a subsequent homolytic hydrogen-abstraction. The following scheme is tentative:



This work is still in progress, and details will be published elsewhere in due course.

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Bromination of Δ^1 Olefins with *N*-Bromosuccinimide

In connexion with a re-investigation of the preparation, structure and reactivity of the bromo compound prepared from 2 : 6-dimethyloctadiene-2 · 6 and *N*-bromosuccinimide[1], an examination of the analogous reactions with some simple Δ^1 olefins has been undertaken. A recent theoretical discussion[2] of the reaction mechanism operative in the latter systems prompts us to present a summary of our findings.

Karrer and Ringli[3], using 1 : 5-hexadiene (diallyl) with *N*-bromosuccinimide, obtained mono- and dibromo derivatives which were formulated as (I ; X = Br) and (II) respectively. In a second paper[4], the crystalline dibromide was recognized as the known conjugated dibromide (IV), and doubt was

$$\underset{\text{I}}{CH_2{=}CH{-}CH_2{-}CHX{-}CH{=}CH_2}$$

$$\underset{\text{II}}{CH_2{=}CH{-}CHBr{-}CHBr{-}CH{=}CH_2}$$

$$\underset{\text{III}}{CH_2{=}CH{-}CH_2{-}CH{=}CH{-}CH_2X}$$

$$\underset{\text{IV}}{CH_2Br{-}CH{=}CH{-}CH{=}CH{-}CH_2Br}$$

$$\underset{\text{V}}{CH_3{-}CH{=}CH{-}CH{=}CH{-}CH_2X}$$

expressed as to whether the liquid monobromide was (I), (III) or (V) (X = Br). Shortly afterwards, however, Karrer and Schneider[5] claimed to have confirmed the original structural assignment for the monobromide by condensing it with acetophenone in the presence of magnesium and diethyl ether and submitting the resulting *tert.*-alcohol to ozonolytic degradation : *c.* 1·44 moles of formaldehyde were liberated, but no acetaldehyde. Two features of this work are questionable : (*a*) the actual isolation of what is undoubtedly the most labile isomeric monobromide ; on further reaction, re-arranged derivatives are apparently produced with extreme ease (further bromination gives (IV), and the alcohol (V ; X = OH) is obtained via the acetate[5]) ; (*b*) the presumed decisiveness of the structural conclusion derived from the degradation experiment, since the investigations of Young and Roberts[6] make it virtually certain that the addendum in the Grignard reaction would combine at the γ- rather than at the α-carbon atom irrespective of whether the bromide were primary (as in III or V) or secondary (as in I).

With the aid of infra-red and ultra-violet spectrographic technique, this structural problem is readily resolved. We find that the liquid monobromide possessing the physical properties reported by the Swiss authors is essentially III (X = Br), admixed with a small amount (*c.* 10 per cent) of I (X = Br). Its infra-red spectrum displays strong absorption at 965 cm.$^{-1}$, characteristic of —CH=CH— groupings, and absent in diallyl, as well as other bands at 915 and 990 cm.$^{-1}$, due to the presence of —CH=CH$_2$ groups. The intensity of the latter band is of the order of one half that of the same absorption in the parent olefin, and the relative intensities at 990 and 965 cm.$^{-1}$, correspond to comparable amounts of the two types of double bond, as present in structure III (X = Br). The ultra-violet spectrum of this monobromide confirms the absence of conjugation. Treatment of the derived diallyl magnesium bromide with carbon dioxide yields the acid I (X = CO_2H), the infra-red absorption of which is markedly different from the bromide but closely similar to that of diallyl between 900 and 1,000 cm.$^{-1}$. The bromide reacts with a concentrated solution of sodium ethoxide in ethyl alcohol—that is, under S_N1 conditions leading to ethoxide substitution at the original position of the bromine atom[7,8]—to produce the conjugated 2 : 4-hexadiene ethyl ether V (X = OEt), which has intense ultra-violet absorption at 2,250 A. and exhibits no infra-red bands attributable to —CH=CH$_2$ groups. The facile prototropic rearrangement occurring in this reaction is in keeping, of course, with the 1 : 4-olefinic character of the parent bromide.

Similar reactivity is evidenced by 1-octene ; and the presence of only one unsaturated centre renders the infra-red structural diagnosis more strictly quantitative. The analytically pure octene monobromide isolated was a liquid mixture containing about 80 per cent of VI and 20 per cent of VII (X = Br), which are partly separable by fractional distillation.

$$\underset{\text{VI}}{CH_3{-}(CH_2)_4{-}CH{=}CH{-}CH_2Br}$$

$$\underset{\text{VII}}{CH_3{-}(CH_2)_4{-}CHX{-}CH{=}CH_2}$$

Carbonation of the derived Grignard complex yielded the structurally homogeneous acid VII (X = CO_2H).

Full experimental details and further discussion will shortly be submitted for publication elsewhere ; but we would add here that we do not accept Dewar's suggestion that these data have a critical bearing on the elucidation of the mechanism of the bromination reaction.

This work forms part of a programme of fundamental research undertaken by the Board of the British Rubber Producers' Research Association.

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Estimation of Non-Ionic Detergents

Although satisfactory methods are available[1,2] for the determination of anionic and cationic active agents, no method has hitherto been found for surface-active agents which do not ionize in solution. Compounds of this type are prepared by the action of ethylene oxide on organic bodies containing OH-groups and have the basic structure, $RO(CH_2CH_2O)_nH$, in which R may be an aliphatic and/or hydrocarbon residue. Since these compounds are achieving growing importance as detergents, wetting agents and emulsifying agents, the need for a method of determination has become urgent.

Several methods have been examined in our laboratories, and a phosphomolybdic acid precipita-

tion method which requires no specialized equipment has proved to be the most satisfactory for our purpose.

Shaffer and Critchfield[3] used silicotungstic and phosphomolybdic acid in the presence of barium to precipitate polyglycols of the 'Carbowax' type having a mean molecular weight of the order of 6,000. After a long tedious procedure, the polyglycol is finally determined by a gravimetric procedure for silicotungstic acid and by a colorimetric method for phosphomolybdic acid. This method, however, is considered too exacting for routine determinations. The following simplified procedure is based on similar principles and is in course of adoption in our laboratories as a standard method for the determination of non-ionic detergents.

The reagents required are: (*a*) detergent solution of known concentration; (*b*) hydrochloric acid solution, 1 vol. of the concentrated acid diluted to 4 vol. with distilled water; (*c*) barium chloride, 10 gm. $BaCl_2.2H_2O$ dissolved in 100 ml. distilled water; (*d*) phosphomolybdic acid (B.D.H.), 10 gm. ($P_2O_5.2OMoO_3.51H_2O$) dissolved in 100 ml. distilled water.

Sulphates, if present, interfere with the determination and must be removed by treatment with barium chloride solution before the following procedure. An aliquot part of solution (*a*) containing a known amount of detergent (usually not more than 100 mgm.) is pipetted into a 250-ml. beaker, to which is added, in the following order, 5 ml. each of hydrochloric acid (solution *b*), barium chloride (solution *c*) and phosphomolybdic acid (solution *d*); the contents are diluted to 150 ml. with distilled water. The yellowish-green precipitate formed is flocculated by raising the mixture to the boil; the beaker is then covered and allowed to stand overnight (18 hours). The precipitate is filtered through a tared No. 4 sintered glass crucible (previously heated for 15 minutes at 100° C. and cooled in a desiccator) washed with a minimum of 100 ml. of distilled water and dried at 100° C. to a constant weight. After two 1-hour periods substantially no change in weight is found.

This procedure establishes the ratio, weight of complex to weight of detergent, for the particular detergent preparation under test.

The results from four individual sets of experiments by different operators are given in the accompanying table.

Wt. of ethylene oxide condensation product (gm.)	Weight of complex (gm.)					Mean deviation expressed as % of mean
	Set 1	Set 2	Set 3	Set 4	Mean	
0·012	0·0336	0·0338	0·0354	0·0358	0·0347	2·5
0·024	0·0695	0·0706	0·0706	0·0728	0·0716	1·8
0·048	0·1458	0·1458	0·1451	0·1436	0·1451	0·5
0·096	0·2824	0·2901	0·2897	0·2894	0·2876	0·9

The reproducibility of the method is thus reasonably good.

On plotting weight of complex against weight of detergent, a rectilinear graph is obtained. This is used as a calibration graph for this particular detergent. Samples or solutions of this same detergent, of unknown concentration, are then analysed by following the procedure detailed above and interpreting the results obtained with the aid of the calibration graph.

We are glad to acknowledge the co-operation of Mr. N. Strafford, chief analyst of the Dyestuffs Division.

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Heterocyclic Compounds from Schiff's Bases

Benzimidazoles have been prepared by oxidation of a mixture of an *o*-phenylene diamine and an aldehyde with cupric salts[1] (for example, cupric acetate), and it has been pointed out[2] that the reaction proceeds by the oxidative ring closure of the mono-Schiff's bases first obtained:

With certain nitro-substituted *o*-phenylene diamines, this method has not been entirely satisfactory in our hands, and we have attempted to close the ring of such Schiff's bases by means of reagents other than cupric salts. We have found lead tetra-acetate an excellent reagent for this purpose, giving high yields of 2-aryl benzimidazoles, and the reaction proceeding very rapidly.

We have extended the method to the synthesis of 2-aryl benzoxazoles by showing that the Schiff's bases of *o*-aminophenol are rapidly converted to the ring compounds by means of this reagent. In this manner, for example, the following compounds have been prepared: 2-(*p*-nitrophenyl)-benzoxazole, m.p. 267–68° (found: N, 11·77; $C_{13}H_8O_3N_2$ requires N, 11·66 per cent); 2-(*m*-nitrophenyl)-benzoxazole, m.p. 211–212° (found: N, 11·8; $C_{13}H_8O_3N_2$ requires N, 11·66 per cent); and 2-(*p*-chlorophenyl)-benzoxazole, m.p. 152° (found: N, 6·15; Cl, 15·6; $C_{13}H_8ONCl$ requires N, 6·1; Cl, 15·45 per cent).

The reaction may be conducted in glacial acetic acid or in benzene. In the latter case it is only necessary to add the calculated amount of lead tetra-acetate to the Schiff's base dissolved or suspended in the solvent, when the mixture becomes warm, and, after the reaction is complete, the benzoxazole may be isolated by conventional methods. Working on 1/100 molar scale, the yields so far obtained appear in many cases to be of the order of 80 per cent of the theoretical.

This method of ring closure is being studied and extended. The results will be published in greater detail elsewhere.

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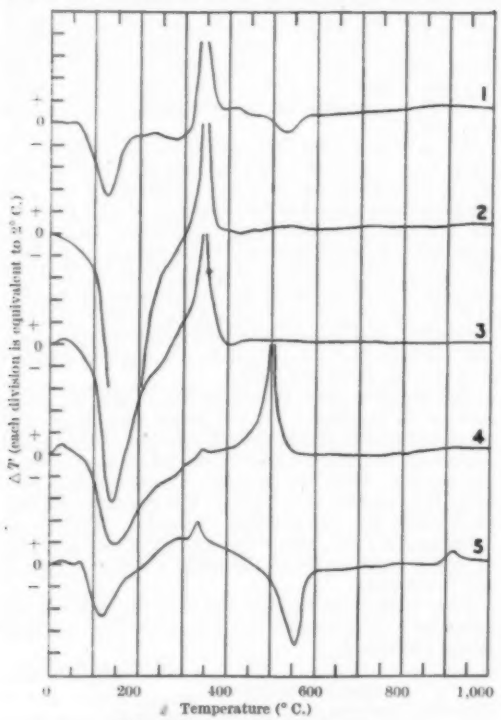
Nature of Free Iron Oxides in Soil Clays

A DIFFERENTIAL thermal analysis examination of soil clays at present in progress with the view of elucidating their mineral composition has provided some evidence regarding the nature of the iron oxide coatings on the clay micelles. One of the clays studied, which had a free iron oxide content of 31 per cent, had been separated from a *C*-horizon sample (depth 48–52 in.) of a soil developed on basic igneous till and had been treated several times with hydrogen peroxide on the steam-bath to remove organic matter. Its thermogram shows a strong exothermic peak at about 345° C. (curve 1 in the graph), which because of its sharp well-defined nature appears to be quite different from the broad, rather diffuse band usually associated with organic matter, but which bears a considerable resemblance to that quoted by Berg, Nikolaiev and Rode[1] for 'cold-precipitated' or 'glowing' hydrated ferric oxide[2].

The similarity of the curves may be readily observed in the graph, where curve 2 is that obtained for 'cold-precipitated' hydrated ferric oxide in this laboratory. The oxide was precipitated from a ferric chloride solution by addition of excess 1 : 1 ammonia at room temperature (about 18° C.), washed free from chloride and dried at 105° C. in the oven. Material dried over phosphorus pentoxide *in vacuo* gives an identical curve. Repeated treatment of the oxide with hydrogen peroxide on the steam-bath—the normal procedure for removing organic matter from soil clays—does not affect the curve appreciably (curve 3). In connexion with the formation of these ferric oxide gels, it is noteworthy that the temperature of precipitation affects the curve very appreciably; for example, precipitation at 100° C. displaces the exothermic peak to 503° C. (curve 4), whereas precipitation at temperatures between 18° and 100° C. causes the peak to appear at temperatures between 345° C. and 503° C. In view of these facts it would seem that the 'cold-precipitated' hydrated ferric oxide occurs as such in the soil and is not formed by any pretreatment, for example, by precipitation during the decomposition of organo-metallic complexes by hydrogen peroxide.



Differential thermal analysis curves.

1, Soil clay, No. 15280; 2, hydrated ferric oxide precipitated at 18° C.; 3, 'cold-precipitated' hydrated ferric oxide treated six times with hydrogen peroxide; 4, hydrated ferric oxide precipitated at 100° C.; 5, soil clay No. 47343

Several other soil clays have since been found to contain this type of ferric oxide, but generally in smaller amounts (cf. curve 5). A survey of the literature reveals that somewhat similar small peaks have frequently been observed on thermograms of soil clays; but they apparently have been interpreted as organic matter incompletely removed. However, the sharpness of the peaks and the constancy of the peak temperature, as well as their occurrence on thermograms of clays from lower horizons of the profile which have been well peroxidized to remove organic matter, seem to exclude this possibility.

Goethite, which gives a strong endothermic effect at 380° C., has been observed in only a few of the soil clays examined.

These iron oxide coatings normally show up only as a diffuse background on X-ray photographs of soil clays, and an electron diffraction examination of four soil clays shows no sign of crystallinity in the coating. It would, therefore, appear that differential thermal analysis is at present the only method of investigating them.

The differential thermal analysis apparatus employed in these investigations is somewhat similar to that described by Grimshaw, Heaton and Roberts[3]: a ceramic specimen holder is used; exothermic peak temperatures are quoted as the temperature of the inert material at the peak; endothermic peak temperatures are corrected to the temperature of the sample at the peak; sample weights for soil clays are 0·2 gm., for iron oxides 0·35 gm.

Further work is in progress, especially with the view of elucidating the conditions of formation of these oxides in the soil, and a full report will be published elsewhere. I would like to thank Prof. G. I. Finch, of the Imperial College of Science and Technology, London, for supplying the electron diffraction data.

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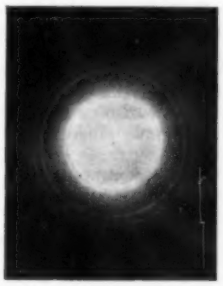
[1] "Thermographia", 85 (Acad. Sci. U.S.S.R., 1944).
[2] See, for example, Fricke and Huttig, "Hydroxyde und Oxyhydrate", 335 (Leipzig, 1937).
[3] *Trans. Brit. Ceram. Soc.*, **44**, 60 (1945).

Structure of Stearic Acid Films on Copper

IN a recent communication[1], Spink, using electron diffraction technique, postulates the presence of copper stearate after a copper surface covered with stearic acid has been heated. Two facts are quoted in support of this hypothesis. (1) When such a film is heated in the diffraction camera, the pattern finally fades at a temperature of 127–130° C., that is, close to the softening point of copper stearate. This observation confirms that of Brummage[2], and also

corresponds well with friction measurements reported by Gregory and Spink[3]. It is generally accepted that both the electron diffraction and the friction evidence are circumstantial and do not offer a direct proof of the presence of the soap. (2) After the acid-covered surface has been heated, the film may be removed in benzene and then deposited on collodion. The resulting film gives an excellent diffraction pattern which is identical with that of copper stearate prepared in the laboratory.



In fact, the second observation does not conclusively prove the presence of the soap on the surface, as claimed, because the same pattern may also be obtained from stearic acid (see photograph), and also from other fatty acids, from esters[4], from normal paraffins[5] and from grease contamination in general[6]. Likewise, the arc patterns attributed by Spink to crystals of copper stearate have been observed in this laboratory in patterns from stearic acid deposited on stainless steel and subjected to rubbing on filter paper.

Thus, while Spink has been able to confirm previous indirect evidence of the presence of copper stearate on a copper surface after heating in the presence of stearic acid, he has not succeeded in producing definite electron diffraction evidence of its existence.

I wish to thank the Chairman of the Anglo-Iranian Oil Company for permission to publish this letter.

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[1] Spink, J. A., *Nature*, **163**, 441 (1949).
[2] Brummage, K. G., *Proc. Roy. Soc.*, A, **191**, 243 (1947).
[3] Gregory, J. N., and Spink, J. A., *Nature*, **159**, 403 (1947).
[4] Coumoulos, G. D., and Rideal, E. K., *Proc. Roy. Soc.*, A, **178**, 421 (1941).
[5] Brummage, K. G., *Proc. Roy. Soc.*, A, **188**, 414 (1947).
[6] Trillat, J. J., and Motz, H., *Trans. Farad. Soc.*, **31**, 1127 (1935).

The Uncertainty Principle

Mr. W. L. Cowley[1] raises a point of some importance to a popular presentation of quantum theory. The understanding of the Uncertainty Principle is confused by there being two quite distinct ideas associated with the one name. Mr. Cowley's discussion of Heisenberg's uncertainty principle relates to the form of it which could be derived from the old quantum theory of Planck, Einstein and Bohr (one may call it 'uncertainty I'). As he remarks, books intended for wide circulation usually introduce the principle in this form, by describing the 'microscope experiment', and often take it no further. However, the connexion between uncertainty I and uncertainty II (which depends on the new quantum theory) is slight. The old quantum theory only recognized the so-called 'wave-particle duality' of light, and not of matter; uncertainty I is a rather artificial statement about the precision of observation practicable with an optical microscope. In the new quantum theory of de Broglie and others, however, the 'duality' is formulated for matter also, and uncertainty II expresses a consequence of this.

In the wave mechanical representation of new quantum theory, a particle is represented by a region of waves, the position of the particle being defined only in so far as the region is limited; but if the wave is such that its amplitude is negligible outside a defined region, then the wave may be shown by Fourier analysis to be comprised of a group of waves with a range of wave-lengths. The smaller the region for which the wave is finite (the more precise the definition of the position where the particle is likely to appear), the more divergent from the mean are the significant components of wave-length, and this divergence defines the range of probable momenta of the particle. Uncertainty II states a relation between the probable ranges of position and momentum of the conceptual particle. It thus expresses an important limitation on the precision with which position and momentum may both be defined, and it is not to be compared with errors in macroscopic experiments to which there are no similar limits.

Mr. Cowley considers the observation of a single electron using a microscope. He raises two specific points: first, that the optical formula for the resolution of a microscope is derived from, as he calls it, the effect of bulk action while only a single photon is involved; secondly, that the optics formula merely expresses a convenient and not a fundamental limit. On fuller consideration, however, one finds that the first point contains the answer to the second. Only one photon is scattered by the electron, and only one point, therefore, of what would normally be an Airy disk is excited; hence there is no evidence as to where the rest of the photons would appear if many were scattered by the electron. To interpret this single observation one must first take the most probable position of the electron to be the point conjugate to the observed photon, and secondly take the probable error (the error as likely to be fallen short of as exceeded) of this to be $0{\cdot}535\,\lambda/A$ (λ is wave-length, A is numerical aperture). It is important to note that both the mean error and the standard deviation of the first assumption are infinite. Mr. Cowley, like most authors who discuss this hypothetical experiment, refers to the 'resolution' of a microscope: however, this is wrong, as only one electron and one photon are postulated, and there is nothing else from which these are to be 'resolved'. The uncertainty in the determination of position of the electron depends on the uncertain association of the 'particle' with the 'wave' in light. The uncertainty of momentum arises from the Compton effect. Nowhere does the 'microscope experiment' depend on any specific property of matter, and therefore it cannot demonstrate any new property of matter.

That the formula given in uncertainty I (after a rather artificial analysis) is similar to that given in uncertainty II (apart from a numerical factor) arises from the fact that a 'wave particle duality' may be formulated for both matter and light, and the fact that Planck's constant determines the relation

between energy, momentum, wave-length and velocity for both. But this does not justify the confusion of the two principles. The 'microscope experiment' illustrates uncertainty I, and neither the 'experiment' nor the principle offers any evidence relevant to uncertainty II. I mention these facts in the hope of contributing to the eventual removal of uncertainty I from its present misleading position in text-books.

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April 9.

[1] Cowley, W. L., *Nature*, **163**, 492 (1949).

H. V. STOPES-ROE agrees with my criticism that the application of the resolution-power formula to the uncertainty principle is irrelevant. His letter conveys the impression, however, that I have concerned myself with out-of-date matter and that the position is quite satisfactory in the new wave-particle theory. I wish to make it clear that my criticism was levelled at an application which is generally accepted throughout the science as sound, and which frequently appears in text-books side by side with analysis similar to that sketched out by Mr. Stopes-Roe. Although the new theory has gone from strength to strength since its introduction by de Broglie and others, I find it impossible to accept, and I am sure many must share my difficulties. The wave-particle duality is disturbing enough; but even more so is the incomprehensible duality of quantum theory logic.

The representation of a particle by a group of waves in a limited region as mentioned by Mr. Stopes-Roe is adversely criticized in "Wave Mechanics of Free Electrons" by G. P. Thomson. It is shown in this book that because the component waves have different speeds, the group will continually change its form or characteristics as it travels along. Apparently the view now held by the orthodox is that two de Broglie waves of very nearly the same frequency and speed V greater than light produce beats of speed U less than light such that $UV = C^2$, where C is the speed of light. This simple formula, by the way, and this is very important, would not hold for a Fourier group. The beat wave is not identified with the particle, therefore, in the manner of Mr. Stopes-Roe. The particle is assumed to be carried by the wave, the latter being identified with the motion or velocity of the particle. Nevertheless, the view that the particle is a bunch of waves is not abandoned. Arguments based upon this conception are allowed to pass unchallenged.

Probably the most startling duality in the theory is that which concerns the fact that de Broglie waves have speeds greater than light, although they are evolved theoretically from the theory of relativity which postulates that speeds cannot exceed light. The arguments justifying the position are so crude as to be valueless. The following is typical and was taken from a popular book meant for the novice, "The Restless Universe" by Max Born: "Simple harmonic waves cannot carry a signal. They are as smooth as oil and each wave crest is exactly like every other, and they go on monotonously for ever. Hence they may well travel faster than light, for the theory of relativity would only be contradicted *if they could be used to send distinguishing signals for the comparison of clocks*" (p. 164). Yet the reader must know that clocks are controlled by a continuous electric wave in his supply main, the signal being a constant frequency. Later the reader learns from the uncertainty theory itself that no measurement can be made or action taken without affecting the motion of the particle concerned. The motion of the particle determines the velocity of the de Broglie wave. Therefore, de Broglie waves cannot go on monotonously for ever, for they change every time an action occurs. Whatever may be the answer to this problem it is not contained in the statement quoted, and to a novice this statement cannot convey anything more than false conceptions.

Beginners are even expected to appreciate the following logic, which is quite typical and is taken from "Wave Mechanics—an Introductory Sketch", by H. F. Biggs. "That this velocity exceeds that of light need, of course, cause us no misgiving from the relativity point of view, since it is the velocity of propagation, not of any mass or energy, but merely of the phase of a hitherto unspecified quantity ψ" (p. 17). The reader has to wait until p. 35 for the specification, if indeed it is such.

There is even duality as to what actually is the uncertainty principle. One aspect is what may be termed inadequate representation, and the other is chance, uncontrolled by Nature, in the actions of fundamental particles. Inadequate representation means that although a point may represent a body under certain conditions it will not do so under others. We need not go to the quantum theory to establish this or to obtain the order of magnitude of the error. A reasonable person would accept that when studying galaxies of stars the errors would be measurable in light years; when in the tool room or macroscope laboratory errors are of the order of a thousandth part of a millimetre; and in the measurement of fundamental particles the error would have to be very small if the measurement is to mean anything. This error may as well be associated with Planck's constant h as with anything else.

The second aspect of the principle involves chance, and my reading leaves me with the view that this has featured in the uncertainty principle since its inception and that it still holds ground.

Modern theory has made the position more nebulous if anything, as many writers of advanced books do not discuss the chance aspect explicitly, whereas others do by still retaining all the older views. The former seem to degenerate into the principle of 'inadequate representation'.

Whether or not the uncertainty principle of chance can be proved is a moot point. I think it can never be more than a faith. Observation for the purpose of proof can only show whether or not something happens which our theories predicted should happen. Non-occurrence of the event revealed by a test may, on one hand, arise because of an uncertainty in Nature; but, on the other hand, we may be in error because of our inability to deal with all the factors of the problem. By accepting the uncertainty principle we imply either blind faith, or that we are satisfied that orthodox authority can adequately deal with any problem, however complex, and deal with it regardless of the number of factors involved. This position is rendered untenable when the first error or irregularity is found in the orthodox.

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